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Volume XLII JUNE, 1949 No. 2

EMBRYOLOGY OF PHAENICIA SERICATA (MEIGEN)[1]

Diptera: Calliphoridae

PART III. THE GASTRULAR TUBE

WILLIAM A. FISH,
Providence College,
Providence, Rhode Island

The author has previously described the embryonic development of *Phaenicia sericata* (Meigen) from the process of fertilization to the formation of the blastoderm (primary epithelium). The purpose of this paper is the presentation of the phases of development involved in the formation of the gastrular or mesodermal tube.

It has already been shown (Fish, 1947) that the cleavage nuclei migrate peripherally, the majority of them penetrating the outer layer of protoplasm, the periplasm. A nucleated coat of protoplasm, the blastema, is formed, which completely envelopes the yolk. The nuclei which penetrate and absorb the germ cell determinant of the dorso-polar surface of the posterior pole form the anlage of the germ cells. The peripheral margin of the blastema then becomes divided into cell territories by clefts. Before these clefts reach the yolk an inner layer of anucleated protoplasm, the inner periplasm, appears and merges with a medial surface of the blastema. The latter now appears doubled in thickness. The cell walls appear first on the peripheral margin of the cell territories and slowly divide the continuous portion of the blastema into separate cells. This stage is the so-called blastoderm. Except for the polar regions, where the cells are complete (the posterior pole first), the blastodermal cells still possess a narrow underlying strip of undivided protoplasm (Plate I, Figs. 1, 2, 3, 4).

THE GERM BAND

In the development of the generalized type of insect, the germ band results from a thickening of epithelial cells along the mid-ventral

[1]Previous articles of this series have been published under the title "Embryology of *Lucilia sericata* Meigen." The change is made here in order to conform with the current usage in David G. Hall's "Blowflies of North America."

line simultaneously with a flattening of cells of the dorsal and lateral walls of the blastoderm. In these respects *Phaenicia sericata* proves exceptional.

The process of differentiation of germ band cells from other epithelial cells of the blastoderm is the most fleeting stage so far encountered. As mentioned above the blastoderm is completed first in the posterior pole. Here also is where the germ band first becomes noticeable.

Shortly before the dorsal and lateral blastodermal cells establish walls on their bases, the epithelial cells of the mid-ventral region, about sixteen cells in width, crowd together, slowly grow in length, and gradually push into the yolk mass (Plate I, Fig. 6). The cells in the middle region of this strip push in farther than the others with the result that the peripheral margin of the ventral surface, originally convex, becomes decidedly flat (Plate II, Fig. 8). This flattening is even noticeable upon surface examination of stained whole mounts.

The epithelial cells that do not take part in the formation of the germ band do not noticeably differ from the original blastodermal cells. Those which originally overlaid the undivided protoplasmic strip have now developed an unusual attachment to it. A delicate protoplasmic stalk joins the cell base (as yet a cell membrane is not present) to the strip and each cell appears like a short stemmed goblet (Plate I, Fig. 2).

As the cells of the germ band elongate and push farther into the yolk, those on its margins undergo marked changes in their geometrical configuration. Each of these marginal cells becomes deeply curved with its concave surface contiguous with a germ band cell. The cells lateral to these marginal ones are usually curved on only one surface,

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EXPLANATION OF PLATE I

FIG. 1. A longitudinal section of a nearly completed blastoderm. Notice the continuous strips of protoplasm underlying all cells except for the polar regions. A—anterior; D—dorsal; N—nucleus; P—posterior; V—ventral; Y—yolk; YC—yolk cell.

FIG. 2. A highly magnified view of two blastodermal cells showing their attachment to the undivided protoplasmic strips. The "stem" of each cell is without a cell membrane.

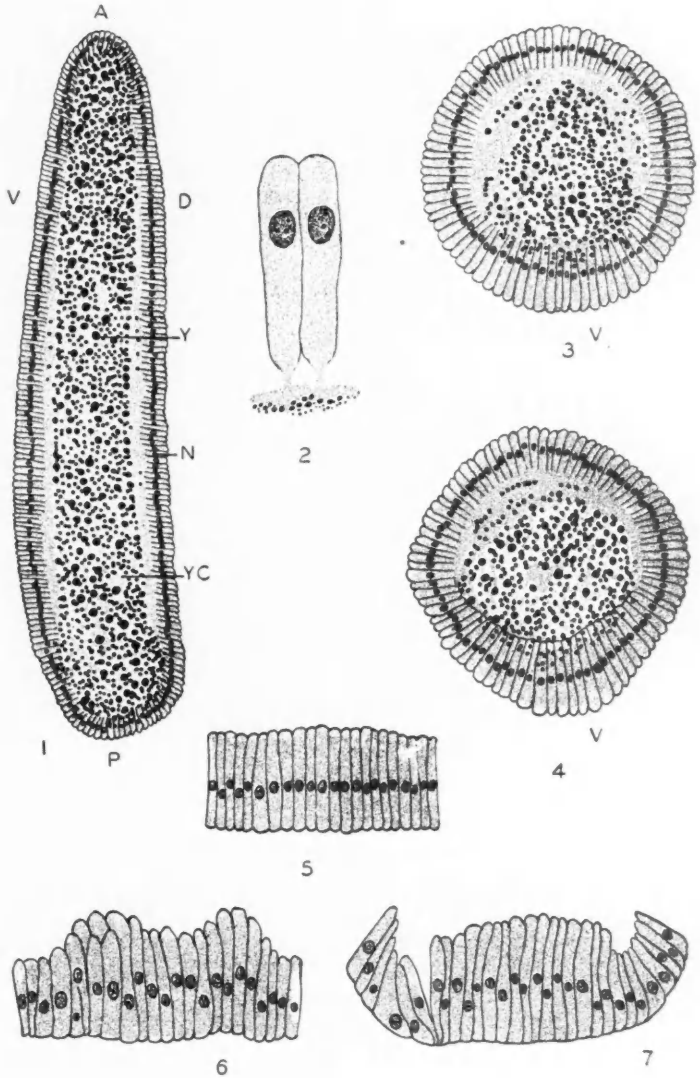
FIG. 3. A cross section of an embryo a little older than that in Fig. 1. Observe the yolk granules within the cells of the ventral region. V—ventral.

FIG. 4. A cross section of an embryo immediately prior to germ band formation. The cells of the ventral region are now complete, that is, each is completely bounded by a cell membrane. Compare this condition with that of the cells in the dorsal region. V—ventral.

FIG. 5. A highly magnified view of the cells of the ventral region of the embryo in Fig. 4. It is the first in a series of eleven illustrations (Figs. 5–15), representing the progressive changes in the transformation of a single layer of cells into a sunken tube.

FIG. 6. A slightly older stage than that in Fig. 5. The cells are more elongate and displaced towards the yolk (not shown). This is the first indication of germ band differentiation.

FIG. 7. The mid-ventral epithelial cells are now more elongate and are easily distinguished from the latero-ventral blastodermal cells. The original convex ventral surface becomes flat and the germ band is consequently more sharply defined.


A
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the concavity towards the marginal cells. The peripheral third of these lateral cells sometimes possesses an enlargement which is hooked around the marginal cell, usually overlapping a part of the latter's peripheral edge (Plate II, Fig. 8). Proceeding laterally these scimitar shaped cells become more and more columnar until they pass insensibly into the typical epithelial cells of the lateral surface. With further germ band development the long axis of the marginal cells comes to lie almost in the same plane as the peripheral margin of the germ band. The space these cells occupied (they originally contacted the yolk) is assumed by the germ band cells.

The next area of the blastoderm to differentiate is the ventral region of the posterior portion of the anterior third of the blastoderm. The same cell configurations as are apparent in the posterior pole are also apparent here. The germ band now proceeds in two directions, anteriorly from the posterior pole and posteriorly from the anterior pole. The last portion of the ventral region to differentiate is the posterior portion of the anterior half of the blastoderm. However, before this final differentiation is accomplished, the gastrular invagination begins in the posterior region of the germ band.

Graber and others have designated the undifferentiated cells of the original blastoderm, since they function as an evelope of the yolk, the serosa. According to their views the differentiation consists of a thinning of the dorsal and lateral sides rather than a thickening of the ventral side.

FORMATION OF THE GASTRULAR GROOVE

In the insects, as a consequence, at least in part, of the large amount of yolk, the phases of gastrulation and layer formation, as concerns phylogeny, are extremely modified and therefore difficult to interpret. The problem centers about the fact that here the invagination gives rise to a cell layer which later differentiates into tissues typically of mesodermal origin instead of a gut epithelium. For this reason objec-

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EXPLANATION OF PLATE II

FIG. 8. The germ band prior to invagination. Observe the configuration of the marginal and ventro-lateral cells. MC—marginal cell.

FIG. 9. The middle portion of the germ band remains in position while the two lateral portions form shallow pockets. This is the first indication of invagination.

FIG. 10. The two lateral pockets narrow and deepen while the middle cells of the band begin to sink inwardly.

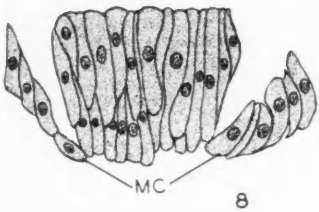
FIG. 11. The middle cells of the band have sunk farther into the yolk forming a single wide furrow.

FIG. 12. The groove is now deep. The cells of the invaginated area are typically wedge-like.

FIG. 13. Closure of the groove begins.

FIG. 14. Closure is almost complete. Notice that it has been accomplished by the cells of the furrow itself.

FIG. 15. The completed gastrular or mesodermal tube. Notice the small lumen and the flat layer of cells covering the tube.



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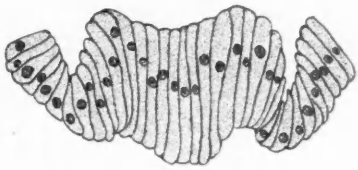

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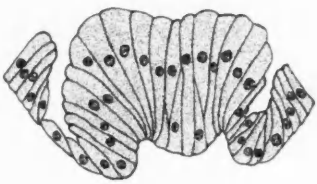

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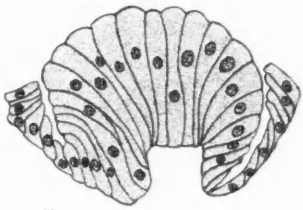

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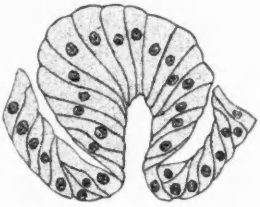

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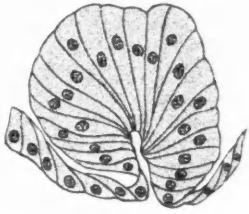

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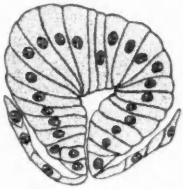

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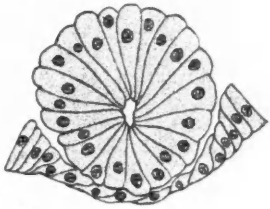

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tions have been raised, in reference to the Arthropoda, as to the validity of the use of the terms gastrulation and gastrula (cf. Chapter VI, Johannsen and Butt, 1941). In this and future papers, the term gastrulation will be used to mean an invagination which results in a differentiation of germ layers, regardless of the subsequent fate of these layers.

With few exceptions gastrulation in insects takes place soon after the germ band has formed. There are two major types of layer formation. In the first type the middle portion of the germ band sinks into the yolk, forming a deep furrow which is converted into a sunken tube. This tube flattens out into a two layered sheet of cells, the inner or lower layer. In the second type the edges of the lateral portions of the germ band grow and separate from the middle portion of the band and then grow together beneath it. The middle piece, now cut off from the lateral portions of the band, forms a single sheet of cells. The type of gastrulation in *Phaenicia sericata* conforms to the first type mentioned.

The steps involved in the development of the gastrular tube may be conveniently divided into two phases; (1) the formation of the ventral groove or furrow, and (2) the closure of the groove.

As mentioned above the invagination of the germ band occurs first in the posterior third of the blastoderm. The speed of band formation and the fact that the ventral furrow is present in both polar thirds before the germ band is formed in the mid-ventral region, suggests that invagination must follow immediately (a minute or two at the most) after band development. As seen transversely the middle part of the band is not the first part to sink into the yolk as is commonly accepted in muscid development. If the stages are observed in the very beginning it will be noticed that two small lateral pockets are present, below and slightly medial to the space formerly occupied by the marginal cells of the germ band (Plate II, Figs. 9, 10). The middle portion of the band still maintains its original position. The originally flat surface of the germ band bordering the yolk now has a definite shallow depression in its middle portion. The middle part

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EXPLANATION OF PLATE III

FIGURES 16–33 represent cross-sectional serials of two entire embryos of slightly different ages from anterior to posterior. There are eight illustrations of the first embryo, completed with Fig. 23. The total length of this embryo is about 1270 microns.

FIG. 16. About 200 microns from the anterior pole. The germ band has started to form in the ventral region. V—ventral.

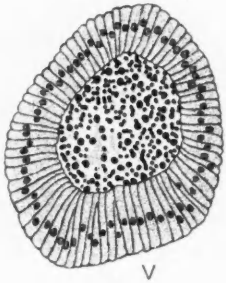
FIG. 17. About 470 microns. The germ band is more pronounced.

FIG. 18. About 520 microns. The band is not yet developed in this region (slightly anterior to the middle).

FIG. 19. About 680 microns.

FIG. 20. About 800 microns. The middle cells of the band have sunk into the yolk.

FIG. 21. About 870 microns. A typical invagination is present.



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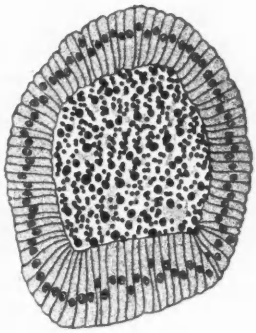

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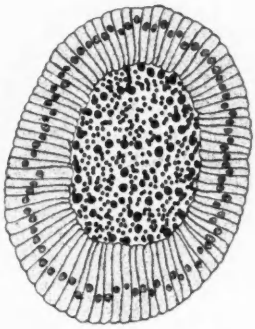

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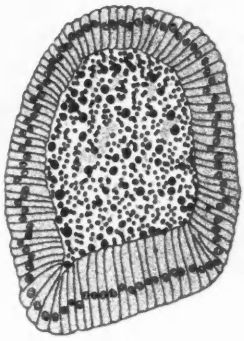

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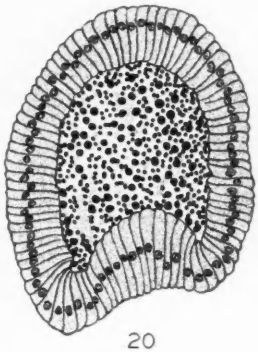

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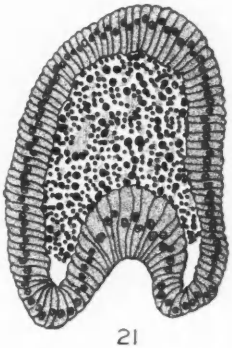

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of the band then sinks into the yolk, establishing a relatively wide furrow (Plate II, Fig. 11). The depression in the mid-region of the band contiguous with the yolk now becomes convex and a typical invagination is present. The middle region apparently continues to sink inwardly and at the same time the groove begins to narrow. A few sections indicate that the elongation of the groove is not a consequence of the middle cells sinking inwardly but rather that the lateral areas grow downward and towards each other. Perhaps it is a result of both processes.

From the initial point of invagination the furrow proceeds both anteriorly and posteriorly. I have not observed a groove originating in this manner in the very tip of the posterior pole. The posterior portion of the furrow is relatively narrow and shallow.

The gastrular groove does not proceed as a continuous furrow to the anterior portion of the blastoderm. Shortly after invagination in the posterior region, the anterior third of the band sinks into the yolk (Plate VI, Fig. 34). Its groove courses both anteriorly and posteriorly. All my sections indicate that it does not attain the sharp curvature of the anterior pole. The posterior portion of the anterior third of the groove widens and two large lateral diverticula appear (Plate VI, Fig. 36). Posteriorly it continues until it meets the posterior furrow, usually near the middle portion of the germ band. This area of fusion is not always uniform.

These stages of development are accompanied by the appearance of one pair of oblique head folds, two transverse folds girdling the posterior portion of the anterior half of the egg and usually three pairs of lateral oblique folds. The dorso-lateral margins of these paired oblique folds never fuse dorsally. In some cases smaller folds may be temporarily present.

CLOSURE OF THE GROOVE

It is perhaps unusual that such a fundamental process as closure of the ventral furrow is not uniform even in embryos with the same parents. The more common type is that described below. Instead of the approach and union of the marginal cells as a method of closing the groove, the closure is made by the cells of the wall of the furrow.

As viewed transversely, the invaginated portion of the embryo can now be divided, for purposes of discussion into four regions: (1)

EXPLANATION OF PLATE IV

FIG. 22. (Continued from Pl. III). About 970 microns.

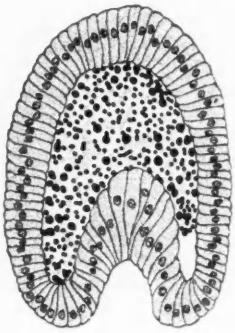
FIG. 23. About 1130 microns. There is some indication of invagination near the posterior pole.

FIG. 24. The first in a series of sections of an older embryo (total length about 1000 microns) taken about 110 microns from the anterior pole. The germ band has not developed here as yet.

FIG. 25. About 160 microns. Notice the clustering of cells at the anterior limit of the gastrular groove.

FIG. 26. About 195 microns.

FIG. 27. About 215 microns.



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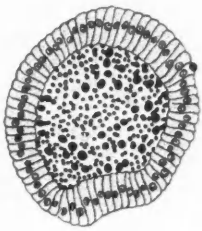

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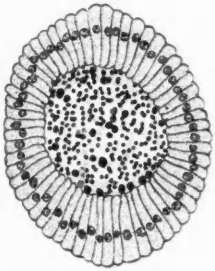

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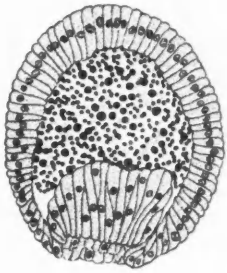

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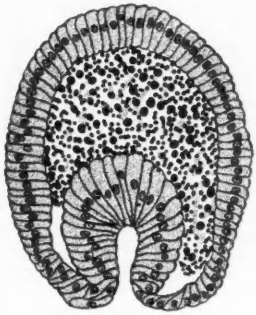

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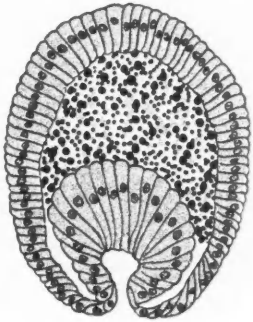

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a thick medial portion bounded internally by the yolk, (2) two lateral portions bounded primarily by the cells of the latero-ventral walls of the blastoderm, and (3) the furrow or groove. Shortly after the groove is about the thickness of a single cell, (Plate II, Fig. 13) a group of about five cells of each lateral portion of the invaginated portion grow towards each other and eventually fuse on the mid-ventral line (Plate II, Fig. 14). This line of fusion lies in the midline of the area formerly occupied by the furrow itself. Gradually the cells of the invaginated area assume a radial disposition forming a thick-walled tube, the gastrular or mesodermal tube (Plate II, Fig. 15). The marginal curved and scimitar-shaped cells originally bordering the germ band now seem to be pulled towards the invaginated area with the result that they temporarily form a flat covering of the gastrular tube. There are about four of these cells on each side of the mid-ventral line (Plate II, Fig. 15).

In general the ventral groove closes first in that region of the embryo where the germ band and furrow were first developed (Plate VI, Fig. 35). It closes last in the region of the head fold just prior to the formation of the amnion. In several embryos closure did not occur at any level until the posterior mesenteron rudiment was well developed.

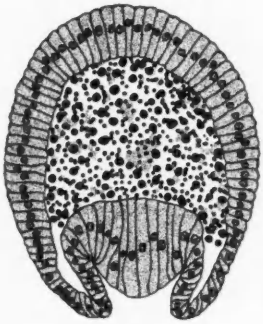
To avoid excessive repetition, the subject of yolk and germ cells will be discussed in Part IV, together with the inner layer and mesenteron rudiments.

SUMMARY AND CONCLUSIONS

1. The germ band is formed by an elongation of a strip of ventral blastodermal cells rather than a flattening of cells of the dorsal and lateral regions of the blastoderm.
2. The germ band is developed first on the ventral surface of the posterior third of the blastoderm and last in the middle region of the blastoderm.
3. Invagination occurs first in the posterior third of the germ band and last in the middle area of the band.
4. The first cells to sink into the yolk are those of the lateral portions of the germ band.
5. The non-embryonic portions of the embryo exhibit six folds.
6. Closure of the groove, a fusion of the cells of the lateral walls of the furrow, results in a long hollow sunken tube.
7. The ventral groove closes first in the posterior region. In the head fold region it remains open until shortly before the formation of the amnion.

EXPLANATION OF PLATE V

FIG. 28. About 295 microns.
FIG. 29. About 355 microns.
FIG. 30. About 595 microns.
FIG. 31. About 705 microns. The groove is almost closed.
FIG. 32. About 845 microns. The groove is open and shallow.
FIG. 33. About 890 microns.



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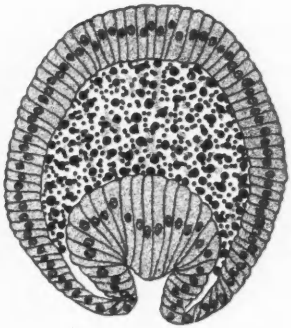

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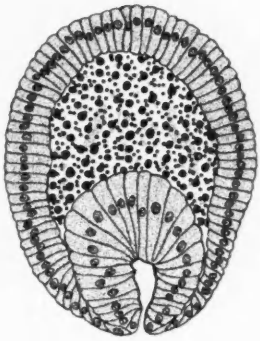

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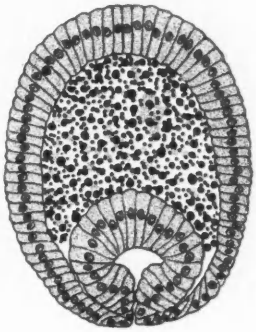

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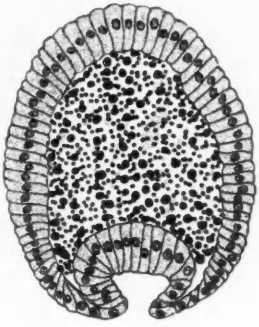

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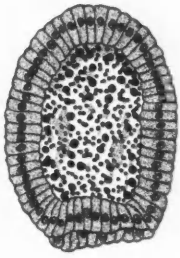

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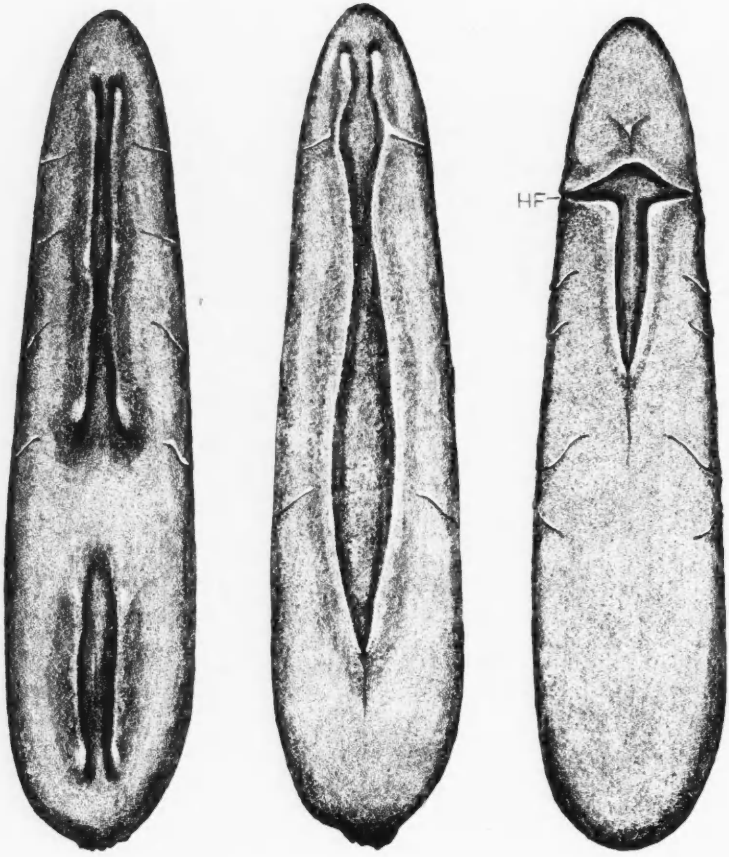

34 35 36

Plate VI has three drawings of stained whole mounts as viewed under reflected light. None of these is the same developmental age as those in the serial sections.

FIG. 34. An early stage in gastrulation, showing two furrows. The one in the posterior region is the older.

FIG. 35. A more advanced embryo showing the invaginated region and the closure of the posterior furrow.

FIG. 36. A still older embryo showing paired lateral folds. In the region of the head fold, paired lateral diverticula of the invagination have developed. HF—head fold.

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AN INTRODUCTION TO THE GENETICS OF HABROBRACON JUGLANDIS (ASHMEAD), by ALBERT MARTIN, JR. The Hobson Press, New York. xii + 205 pages, 19 illustrations and three tables. 1947. Price, $3.50.

This book, one of relatively few of its kind, brings together information on both the genetics and general biology of a well known species, in this instance the parasitic wasp *Habrobracon juglandis (Ashmead)* (=*Microbracon hebetor* [Say]). It is, as its author states, a summary designed for students of Habrobraconology. Although it is intended primarily as a text, its scope and design make it useful as a reference as well, both for entomologists interested in the genetical aspects of their subject and for geneticists interested in entomological aspects of theirs. The introduction includes, among other things, statements on systematics, distribution, reproduction, development and metamorphosis. Descriptions of size, color, external morphology, internal and external genitalia, sex differences and sex reactions of adults follow, together with a brief account of gametogenesis in relation to oviposition and development. Methods (and precautions) for culturing both the wasp and its host are concisely stated; also included are a brief life history, methods of examination and preservation, and methods of recording data. A descriptive list of more than a hundred spontaneous, x-ray-induced, and thermally-induced mutations is given. Normal sex conditions and their deviates (gynanders and other mosaics, intersexes, impaternate females, zygous males, etc.) are discussed, and their relations to mode of reproduction, ploidy, mutation, degree of relationship of parents, variations of sterility, cell size, secondary sex characters, sex reversal and sex behavior are emphasized. Various theories of sex determination (to date the central problem in genetic research on *Habrobracon*) are reviewed and the complementary factor and multiple sex allele theories are clearly and concisely set forth, together with their supporting evidence. The question is raised whether these theories, now experimentally verified for *Habrobracon*, may be extended to the Hymenoptera in general. The formula for the possible number of different females in a series of n alleles should be $(n^2-n)/2$ instead of $(n2-n)/2$, obviously a typographical error (p. 95). The four now known linkage maps (10 are possible, since $2n=20$) are discussed with special reference to the history of their construction; methods of detecting and measuring linkage, with some modifications necessary for *Habrobracon*, are systematically treated. It is shown that *Habrobracon* is highly responsive to different conditions of environment, and variations of eye color, body color, body size, fecundity, hatchability, behavior, development, mutation, sex ratio and gametogenesis are discussed in relation to such factors as temperature, humidity, irradiation and quantity of food. In conclusion, the author reviews some of the advantages of *Habrobracon* for genetic research and points out a number of interesting problems awaiting investigation.

A number of useful illustrations and tables are included, together with an especially valuable glossary. The bibliography is extensive and includes a number of important and useful references in addition to those on *Habrobracon*. Abundant text citations greatly facilitate reference to original papers.—RAY MOREE.

VARIATIONS, DURING DEVELOPMENT, IN THE RESISTANCE OF THE GRASSHOPPER EGG TO A TOXIC SUBSTANCE

ELEANOR H. SLIFER,
Department of Zoology, State University of Iowa,
Iowa City, Iowa

INTRODUCTION

In a series of experiments with dyes it has been shown that the hydropyle of the grasshopper egg, and certain of the other egg coverings as well, undergo striking changes as development proceeds (Slifer, 1949). During the first five days, at 25°C., after it is laid only the chorion of the intact, living egg stains and no dye passes beyond the thin, primary wax layer[1] which waterproofs the inner surface of the shell. As soon as the hydropyle is secreted (as a part of the chitinous cuticle) between the 5th and 7th days the primary wax layer breaks down and dyes are then able to reach the newly-formed hydropyle and to stain it. Before diapause sets in, ten to twelve days later, the hydropyle loses its capacity for staining. This is due to the waterproofing, at this time, of the outermost portion of the hydropyle by a secondary wax or wax-like layer which is secreted by the hydropyle cells. This layer protects the egg during diapause throughout which period the hydropyle is highly resistant to staining. Towards the end of diapause the secondary wax layer is disrupted and during the later stages of development the hydropyle agains stains readily. The dyes which were used penetrate only so far as the inner edge of the striated layer of the hydropyle and have no effect on the embryo which continues its development unharmed.

The experiments just summarized demonstrate the occurrence of permeability changes in the hydropyle and other structures but they present one disadvantage. The penetration of dyes is slow, requiring a week or more for satisfactory results, and, since the egg continues to develop during this time, it is not possible to decide with much exactness just when a change takes place. A better material than a dye for this purpose would be one (1) which would not affect the diapause hydropyle but (2) which would both stain and penetrate that of the developing egg and (3) which would be sufficiently toxic to stop development and kill the embryo after passing through the hydropyle. After trying a variety of substances, a solution of iodine in potassium iodide was found to meet these requirements. The results of experiments with this solution are presented below.

MATERIALS AND METHODS

Melanoplus differentialis eggs of the desired age and with a known temperature history were removed from their pods and all debris and

[1]Beament (1946a, 1946b, 1946c, 1948) has described the waterproofing of the egg of *Rhodnius prolixus* by thin layers of wax and Slifer (1946, 1948b, 1949) has reported the presence of wax layers in the egg of *Melanoplus differentialis*.

spoiled eggs discarded. The sound eggs remaining were washed repeatedly with distilled water, and, if the eggs were old enough, a sample was dissected to be certain that the embryos had reached the expected stage of development. From 40 to 100 eggs—the number depending upon how many were available—were then placed in a 50 cc. Erlenmeyer flask and enough of a 1% solution of iodine in 10% potassium iodide added to cover the eggs about half way. The flasks were corked and set in an incubator kept at 25°C. Each day or, at most, every other day, the flasks were filled to the top with distilled water. This was poured off at once and insured a complete change of the gases inside the flasks. Fresh I-KI solution was then added and the flasks corked again and returned to the incubator. On the 5th day the eggs were removed from the flask and the extent to which the iodine had affected each egg determined. Eggs less than 10 days old, in which the chitinous cuticle had not yet formed, or was still delicate, were dissected in Ringer's solution and the embryo (if present), yolk, membranes and shell examined. Those over 10 days old were dried thoroughly on filter paper and then placed in a dish of xylol. Here the chorion was removed (Slifer, 1948a) and the condition of the hydropyle, egg contents, etc., noted. In a small number of eggs in some experiments iodine entered through minute injuries or imperfections in the chitinous cuticle. If the hydropyle had retained its natural color such eggs were classed with those which had not been affected by the iodine.

RESULTS

Eggs one to five days old.—The effects of an I-KI solution on young eggs in which the chitinous cuticle has not yet formed are extremely interesting. All who have handled eggs less than five or six days old know that they are very soft and easily damaged. In spite of this these eggs are highly resistant to the entrance of iodine (Fig. 1). The chorion itself stains deeply, the color moving gradually forward from the posterior end where minute pores are present in the exochorion (Slifer, 1949), but the primary wax layer on the inner surface of the chorion prevents the iodine from passing into the yolk.[2] Development soon stops in such eggs and this suggests that at least small quantities of the iodine or potassium iodide may reach the interior of the egg; but the yolk remains normal in color and consistency. This surprising resistance to the penetration of iodine correlates nicely with the facts, already known, that the eggs do not take up water during this period (Slifer, 1938) and that dyes will not pass beyond the inner surface of the chorion (Slifer, 1949).

Eggs from five days old to diapause.—Water absorption by the egg begins towards the close of the 1st week at 25°C. and this coincides with the formation of the chitinous cuticle with its specialized area, the hydropyle (Slifer, 1938). Evidently the primary wax layer, in some way as yet unexplained, breaks down or is disorganized and

[2]If these eggs are dried, treated with xylol for 15 minutes and then examined, the yolk will be found colored brown by the iodine. As soon as the wax layer is destroyed, the iodine passes rapidly from the chorion into the egg contents. Comparable results were obtained with dyes (Slifer, 1949).

from then on the egg is protected, instead, by the tough, resistant chitinous cuticle which, except at the hydropyle, is highly impermeable. During the fifth, sixth, and seventh days at 25°C., while the hydropyle is being secreted, the resistance of the egg to iodine drops sharply and by the 8th day iodine is found coloring the hydropyle of every egg (Fig. 2). The hydropyle in some eggs stains intensely over its whole surface while others show patches of various shades of reddish-brown on an unstained background. Between the tenth and twentieth days at first in an increasing and later in a decreasing number of eggs the iodine passes through the hydropyle and damages the egg contents (Fig. 1). The maximum effect is found about the sixteenth day. The yolk in such eggs is darkened and the embryos are hardened, sometimes brown in color, and, quite obviously, dead. Development is usually also arrested in those eggs which show discoloration only at the hydropyle. This may be due to the entrance of small but toxic quantities of the iodine and potassium iodide or to the inability of the

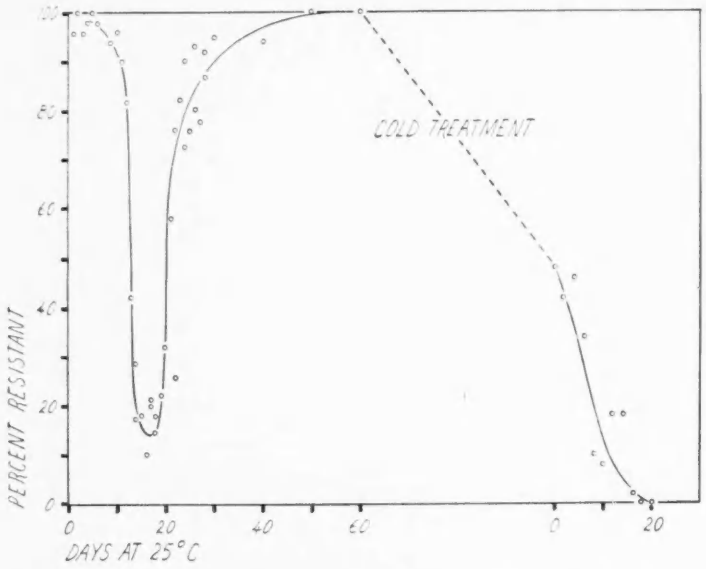

FIG. 1. *Penetration of iodine into egg contents.* Eggs of *Melanoplus differentialis* of various ages treated with a 1% solution of iodine in 10% potassium iodide for five days at 25° C. Diapause begins near close of third week. Broken line represents time spent at 5° C., (usually four months) during which diapause was broken. Hatching starts 18 to 20 days after cold-treated eggs are returned to 25° C. Abscissa: days at 25° C., since eggs were laid (left side of graph) or since eggs were removed from cold (right side of graph). Ordinate: percentage of eggs with no iodine visible in egg contents.

egg to take up water from a solution of this concentration. Probably both have an effect.

This extreme susceptibility of the egg to iodine persists until the close of the second week at 25°C. Then, beginning about the fifteenth day a few eggs show no discoloration of the hydropyle after five days in the iodine solution (Fig. 2). Throughout the next week the resistance to iodine rises at first slowly and then more rapidly. An examination of the curves in Figures 1 and 2 suggests, at first glance, that the onset of iodine resistance is gradual. Another interpretation, however, is possible. The eggs in any lot, no matter how carefully selected at the beginning of an experiment, do not develop at exactly the same rate (Slifer, 1932). A very few will be farther along than expected and a larger number will lag behind. It is quite possible, then, that the rising portions of the curves shown in Figures 1 and 2 are composite and that the actual onset of resistance in any single egg occurs within a much shorter time.

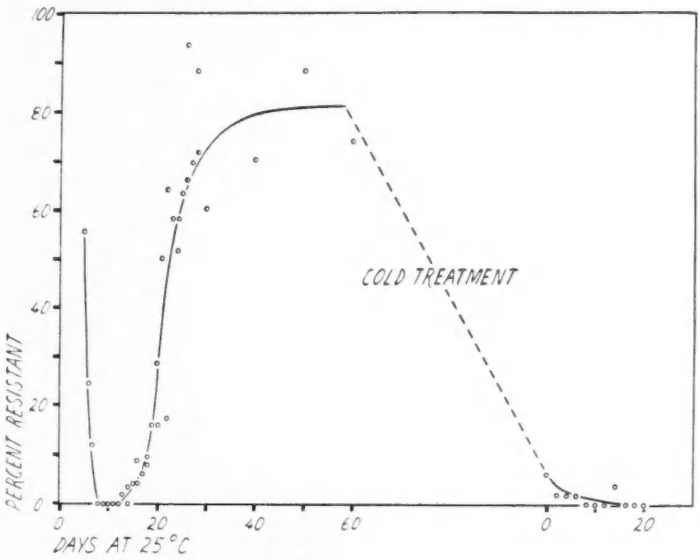

FIG. 2. *Resistance of hydropyle to staining by iodine.* Eggs of *Melanoplus differentialis* of various ages treated with a 1% solution of iodine in 10% potassium iodide for five days at 25° C. Diapause begins near close of third week. Broken line indicates time spent at 5° C., (usually four months) during which diapause was broken. Hatching begins 18 to 20 days after cold-treated eggs are returned 25° C. Abscissa: days at 25° C., since eggs were laid (left side of graph) or since eggs were removed from cold (right side of graph). Ordinate: percentage of eggs in which hydropyle retains its natural color.

Eggs in diapause.—During diapause only a small percentage of the eggs treated with iodine solution show any discoloration of the hydropyle[3] and the great majority of them show no effect of the reagent (Figs. 1 and 2) aside from the browning of the chorion. If diapause eggs which have been in an I–KI solution for five days and which have retained the natural pale brownish-yellow color of the hydropyle are treated with xylol to break diapause (Slifer, 1948a), dried and incubated at 25°C. on moist filter paper almost every one will be found to be developing and the majority ready to hatch three weeks later (Table I). Diapause eggs, then, are highly resistant to iodine solution. This contrasts sharply with their behavior in the period before diapause begins.

Eggs with diapause broken by xylol.—Since treatment with xylol or other wax solvents breaks diapause (Slifer, 1946, 1948a) one would

TABLE I

EFFECTS OF IODINE SOLUTION ON VIABILITY OF DIAPAUSE EGGS

Two hundred 45-day-old diapause eggs selected for presence of partially pigmented eyes at posterior end. One hundred of these in 1% iodine in 10% potassium iodide solution for 7 days at 25° C. Examined and 86 found with natural colored hydropyle. These treated for 30 minutes with xylol to break dispause, dried and incubated on moist filter paper at 25° C., for 20 days. One hundred control eggs on moist filter paper at 25° C., for duration of experiment.

	Eggs Developing	Eggs Still in Diapause	Eggs Spoiled	Percent of Viable Eggs Developing
I–KI treated eggs	81	3	2	96.4
Control eggs	0	97	3	0.0

expect that eggs exposed to such reagents would be particularly susceptible to injury by iodine. This proves to be the case. If diapause eggs which have been treated with xylol are dried thoroughly and then placed in I–KI solution the hydropyle of each turns a very dark brown or black and the iodine promptly passes into the egg, discolors the yolk and kills the embryo. With the waxy layer which normally protects it dissolved away, the egg quickly succumbs to this toxic substance.

Eggs with diapause broken by cold.—The reaction of grasshopper eggs to iodine solutions during the later stages of development was studied with eggs in which diapause had been broken by exposure to low temperatures (approximately 5°C.) for several months. Their behavior (Figs. 1 and 2) was found to be very similar to that of eggs which had not yet reached diapause. The hydropyle of every or very nearly every egg was stained by the iodine (Fig. 2) and a large percentage, after five days in the solution, contained dead embryos and badly discolored yolk (Fig. 1). The wax layer at the hydropyle has been disorganized or broken down during the prolonged exposure of these

[3]It is possible that in those eggs which do show some discoloration, the wax which is secreted into the outer layer of the hydropyle by the cells below it has not penetrated all the way to the outer surface at every point.

eggs to cold and is, consequently, no longer able to prevent the entrance of iodine. The hydropyle remains in this condition until the egg hatches.

An interesting phenomenon was noted in cold-treated eggs which had been allowed to develop for eight days, or longer, at 25°C. and were then exposed to a solution of iodine. The pleuropodia (which are responsible for the production of the hatching enzyme (Slifer, 1937)) and the region of the chitinous cuticle which is in contact with them turn brown in these eggs. This occurs before any signs of injury to the embryo are apparent and while the dorsal body wall, where the heart is forming, is still beating regularly and vigorously. Apparently some component of the secretion which is produced by the pleuropodia is readily affected by traces of iodine.

DISCUSSION

The egg of *Melanoplus differentialis*, at 25°C., passes through the following stages:

1. *First to fifth day.* Primary wax layer on inner surface of the chorion waterproofs the egg. No water absorbed during this period.
2. *Fifth to about the sixteenth day.* Chitinous cuticle, including the hydropyle, secreted by the serosa. Primary wax layer disrupted and water is then absorbed through the hydropyle.
3. *Diapause.* Secondary wax layer secreted and waterproofs hydropyle. Water absorption stops.
4. *End of diapause to hatching.* Secondary wax layer breaks down and water is again taken up through the hydropyle.

During two periods in their development, then, *Melanoplus differentialis* eggs, protected by thin layers of wax or wax-like substances, are resistant to the entrance or loss of water and during two other periods, when the wax layers are imperfect, water is taken up by or passes out of the egg very readily.

In the present experiments the reaction of the egg to iodine solutions at any particular stage has been found to be closely correlated with its permeability to water at that time. During the first five days of development no iodine can be seen inside the egg even after several days exposure to that reagent. The protection afforded by the primary wax layer on the inner surface of the chorion is surprisingly effective considering the fact that it is probably less than 0.2μ in thickness (Slifer, 1948b); but this protection is not quite perfect for development stops in these eggs even though no iodine is visible inside them. During diapause the thick, tough, impermeable chitinous cuticle and the hydropyle with its outer layer waterproofed by a waxy material entirely prevent iodine from reaching the egg contents. The embryos in the egg show no signs of injury and, when diapause is broken, resume development and hatch.

During the second and fourth periods, on the other hand, the effects of iodine on the egg are altogether different. These are periods of water uptake. With the wax seal on the hydropyle still incompletely formed (period 2) or partially disrupted (period 4) iodine is now able to penetrate the hydropyle and to reach the egg contents. Of the eggs treated with iodine during these two stages, a very high percentage is promptly killed.

A knowledge of the fact that at two particular periods in their development the eggs of this species of grasshopper are susceptible to the action of a toxic agent while at others they are highly resistant to it may be of some interest to those who are working in the field of applied entomology.

CONCLUSIONS

1. The primary wax layer on the inner surface of the chorion of the *Melanoplus differentialis* egg acts as a barrier to the passage of iodine (dissolved in a solution of potassium iodide) during the first five days after the eggs are laid. However, traces of iodine or potassium iodide probably do penetrate the wax layer for development stops in these eggs even though no effect on the yolk can be seen.

2. From the fifth to about the sixteenth day at 25°C. the eggs are highly susceptible to iodine poisoning and the newly-formed hydropyle is discolored by this substance as it passes through it into the yolk and kills the embryo.

3. During diapause the hydropyle, now protected by the secondary wax layer, is not stained or penetrated by iodine and the eggs are entirely unharmed even after long exposure to this reagent.

4. When diapause is over the hydropyle again stains readily in a solution of iodine and the iodine passes through it, darkens and coagulates the yolk and kills the embryo.

5. There is a close correlation between the permeability of the hydropyle to water, the presence of a layer of wax or wax-like material and the susceptibility of the eggs to injury by iodine.

6. A knowledge of the periods when the eggs are least resistant to a toxic agent may be of some value to those who are interested in the control of grasshoppers.

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PARASITES OF THE EUROPEAN CORN BORER IN DELAWARE[1]

DONALD MacCREARY[2] AND PAUL L. RICE,[3]
Delaware Agricultural Experiment Station, Newark

Since the discovery of the European corn borer, *Pyrausta nubilalis* (Hbn.) in Delaware in 1934, this insect has increased in numbers until it is now the most important pest of corn in the State. In the past, the only available control methods have been cultural practices—the destruction of overwintered borers, the use of resistant varieties, and the adjustment of planting dates to avoid losses caused by attacks of the first-brood larvae. Insecticides, effective for corn borer control, are of comparatively recent origin. Furthermore, until very recently, there has been no equipment capable of applying insecticides successfully to corn after it had reached the tasseling stage.

In the search for methods of reducing the borer population, the establishment of natural enemies of this introduced pest has received consideration. Large numbers of parasites have been released in Delaware during the period 1941–1946[4]. Information that has been gathered relative to their abundance from the time of release through 1947 provides a basis for the present report.

The utilization of parasites has an advantage, in that once successfully established, they continue to destroy a certain proportion of the borers without further aid from man. Their continued presence after colonization is subject, naturally, to many factors, any one of which may reduce their numbers or even eliminate them. Among unfavorable and limiting conditions are weather, attack by secondary parasites, and poor synchronization with the host insect.

COLONIZATION OF PARASITES

The Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, has imported and successfully established several foreign parasites that have proved to be effective enemies of the European corn borer.

In 1941, representatives of the Bureau from the Moorestown, New Jersey, laboratory liberated small colonies of *Macrocentrus gifuensis* Ashm. at Kirkwood, Dover, and Stockley, thus providing a possible nucleus of this species in each county. The tachinid fly, *Lydella stabulans*

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[2]Associate Research Professor, Entomology.

[3]Formerly Associate Entomologist; resigned September 15, 1945. Now, Professor of Biology, Alma College, Alma, Michigan.

[4]All parasites were obtained from, and all corn borer larvae processed by, the European Corn Borer Laboratory of the U. S. Bureau of Entomology and Plant Quarantine, Moorestown, New Jersey.

grisescens R. D., also was released at Stockley in the same year and, at Kirkwood, in 1943.

After 1943, it became impossible for the Bureau to carry on large-scale colonization work in Delaware without local assistance. Accordingly, a cooperative program was outlined which provided for the purchase and subsequent release of all parasites that could be appor-

TABLE I

LIBERATIONS OF EUROPEAN CORN BORER PARASITES IN DELAWARE BY LOCATIONS, YEARS,[1] AND SPECIES

COUNTY	LOCATIONS	YEAR	PARASITES					TOTALS	
			M. gifuensis	*E. viridulus*	*H. punctorius*	*L. stabulans grisescens*	*C. annulipes*	By Years	By Locations
New Castle	Hockessin	1944	3967			496	495	4958	
		1945	1976					1976	
		1946	2000					2000	8934
	Kirkwood	1941	1984					1984	
		1943				600		600	
		1944	4127		496			4623	
		1945	1935		495		413	2843	
		1946	1992	2000	491			4483	14533
	Townsend	1944	6078			500		6578	
		1945	1952					1952	
		1946	1995					1995	10525
Kent	Dover	1941	1981					1981	
		1944	5986		491	497		6974	
		1945	1914		495		499	2908	
		1946	1990	2000	500			4490	16353
	Farmington	1944	4096					4096	
		1945	1950					1950	
		1946	1962					1962	8008
	Frederica	1944	4117			496		4613	
		1945	1887					1887	
		1946	1986			393		2379	8879
Sussex	Stockley	1941	1979			197		2176	
		1944	4134		495			4629	
		1945	1954				496	2450	
		1946	1854	2000	496		326	4676	13931
	Laurel	1944	4107					4107	
		1945	1941					1941	
		1946	1935					1935	7983
	Milton	1944	4109					4109	
		1945	1952					1952	
		1946	1949					1949	8010
Totals			81789	6000	3959	3179	2229	97156	97156

[1]Total parasites released in 1941, 6141; 1943, 600; 1944, 44687; 1945, 19859; 1946, 25869.

tioned to the State. Under this program, systematic borer collections were to be made in the fall of each year, so as to provide data on the establishment of parasites and to measure their effectiveness in reducing the overwintering borer population.

The parasites were collected in the morning from the incubation rooms at the Moorestown laboratory, placed in refrigerated containers,

and transported by automobile to the release points in Delaware, where they were liberated the same day or, in a few cases on the following day, at predetermined sites along the margins of corn fields, or at other suitable locations. Mortality during the transportation period was so low as to be of no consequence.

Sizable releases were begun in 1944 and continued through 1945 and 1946. Five species of parasites were liberated, totalling 97,156 individuals. These were divided as follows: ***Macrocentrus gifuensis*** Ashm., 81,789; ***Eulophus viridulus*** Thoms., 6,000; ***Horogenes punctorius*** Rom., 3,959; ***Lydella stabulans grisescens*** R. D., 3,179; and ***Chelonus annulipes*** Wesm., 2,229. In Table I, the distribution of these species is shown by locations, by years, and by species; a summary of these data is included as Table II.

TABLE II

SPECIES OF EUROPEAN CORN BORER PARASITES LIBERATED AT VARIOUS SITES IN DELAWARE, 1941 TO 1946, INCLUSIVE

SPECIES	NEW CASTLE COUNTY			KENT COUNTY			SUSSEX COUNTY			TOTALS
	Hockessin	Kirkwood	Townsend	Dover	Frederica	Farmington	Stockley	Laurel	Milton	
M. gifuensis	7943	10038	10025	11871	7990	8008	9921	7983	8010	81789
E. viridulus	.....	2000	.....	2000	.....	.....	2000	.....	.....	6000
H. punctorius	.....	1482	.....	1486	.....	.....	991	.....	.....	3959
L. stabulans grisescens	496	600	500	497	889	.....	197	.....	.....	3179
C. annulipes	495	413	.....	499	.....	.....	822	.....	.....	2229
Totals	8934	14533	10525	16353	8879	8008	13931	7983	8010	97156

RECOVERY OF PARASITES

As previously indicated, the extent of parasitism by various species was determined through collecting full-grown overwintering borers and forwarding them to the Moorestown laboratory for processing. Such collections were made during the fall and winter months of the years 1943 to 1947, inclusive.

In 1943, a plan was outlined to provide information on the dispersal of parasites from Stockley, the original parasite release site in Sussex County. Concentric circles of one-, three-, and five-mile radii, with Stockley as the center, were drawn on a map (fig. 1). The area between the inner circle and that with the three-mile radius was divided into eight segments and the area beyond this, to the outer circle, into 16 segments. Each of these segments contained 3.14 square miles, the same area as that within the inner circle. These segments were numbered consecutively, with the central area designated as number 1. Collections were made from this area and from all even-numbered segments. In 1944, an additional circle with a seven-mile radius was added; this

was divided into 24 segments of 3.14 square miles each. Collections in this and subsequent years were made from the central area and all odd-numbered segments.

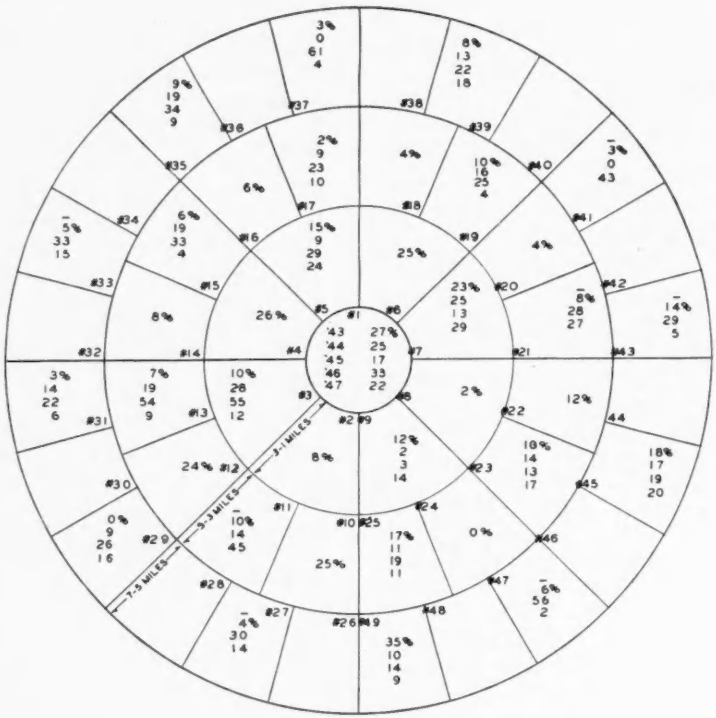

FIG. 1. Diagram of Stockley special-study area, showing percentage of European corn borer larvae parasitized, years 1943 to 1947, inclusive. Parasites were colonized at the center of the inner circle. Borer collections were made in 1943 in the central area and in all even-numbered segments, while those in subsequent years were made in the central area and in all odd-numbered segments. A dash in any percentage column indicates no collection.

A similar study-area was established at the Kirkwood colonization site in 1945 (fig. 2). As with the Stockley area, the seven-mile circle was not utilized until the second year. Here, as well as at Stockley, borer samples consisted normally of 50 full-grown larvae. In several instances, however, the number actually secured was below this, due

either to the limited amount of corn grown in a segment, or to a low rate of borer infestation.

In addition to the Stockley and Kirkwood liberation points, parasites were released at seven other sites in the State; namely, Hockessin, Townsend, Dover, Frederica, Farmington, Milton, and Laurel. At

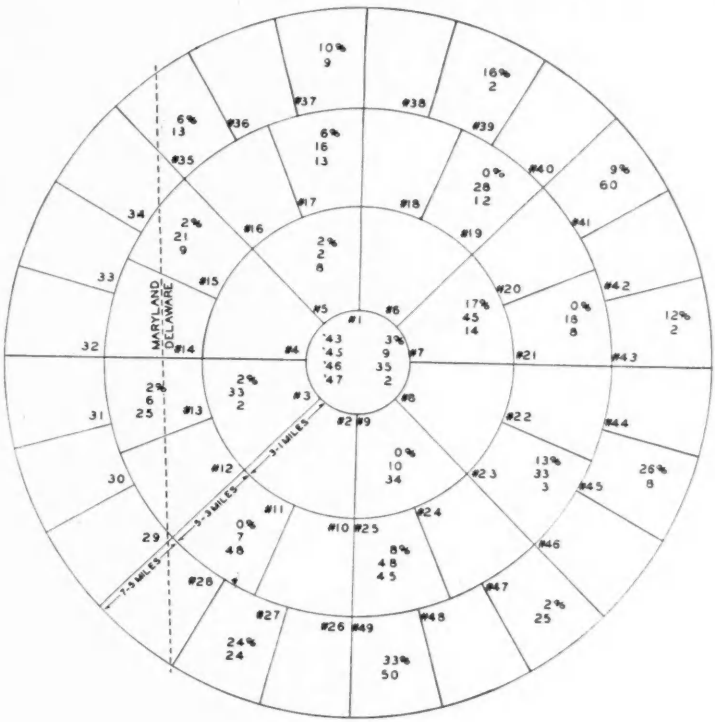

FIG. 2. Diagram of Kirkwood special-study area, showing percentage of European corn borer larvae parasitized, years 1943, 1945, 1946, and 1947. Parasites were colonized at the center of the inner circle. Collections in five- to seven-mile zone, years 1946 and 1947 only.

each of these locations, collections of 200 borers were made during 1945 and 1946. These locations are indicated in figure 3.

In 1945, an additional effort was made to obtain data on parasitism of borer larvae without regard to the parasite release points. Accordingly, 50-borer collections were made at approximately 10-mile intervals

along the main highway from Claymont in the north to Rehoboth in the south. These collection points are shown in figure 4.

In 1947, the U. S. Bureau of Entomology and Plant Quarantine devised a uniform plan of sampling which was to be followed in the states along the Eastern Seaboard. The State was divided into sections 10 miles square (fig. 5), or fractions thereof resulting from irregularities in the boundary lines. Fifty-borer samples were obtained from near the center of each of 30 such squares.

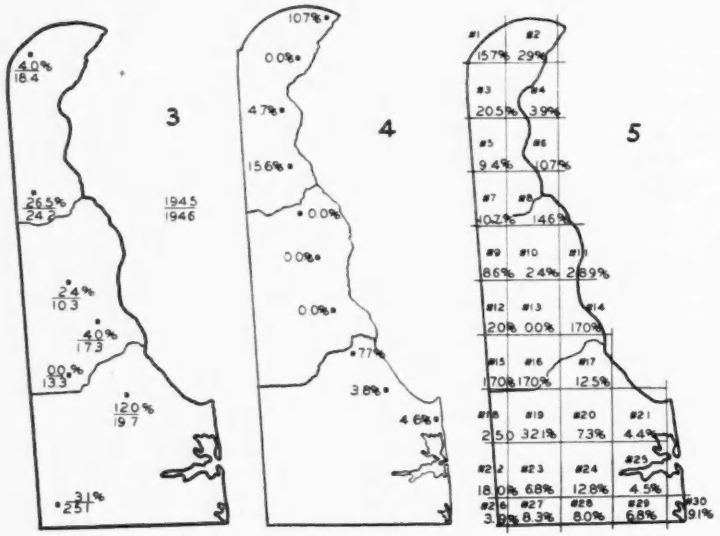

FIG. 3. Percentage of European corn borer larvae parasitized at seven release points in Delaware, 1945 and 1946.

FIG. 4. Percentage of European corn borer larvae parasitized at supplementary collection points, Delaware, 1945.

FIG. 5. Percentage of European corn borer larvae parasitized in 10 x 10-mile sections, state-wide survey, Delaware, 1947.

STOCKLEY—The collection of borer larvae for the recovery of parasites began in 1943 at Stockley. Table III summarizes the data for this release point. With the exception of *Bassus agilis* Cresson, a native form reared in 1945, all parasites recovered here were the tachinid fly, *L. stabulans grisescens*. During the five-year period, 106 collections totalling 3,559 live borers were made. Only four of these did not include larvae attacked by this species.

The percentage of borers parasitized in the years 1943, 1944, 1945, 1946, and 1947, were 15.1, 12.3, 12.9, 28.1, and 13.8, respectively;

TABLE III

PARASITISM OF EUROPEAN CORN BORER LARVAE BY *Lydella stabulans grisescens* R. D.[1] AT VARYING DISTANCES FROM THE STOCKLEY COLONIZATION POINT, DELAWARE, 1943 TO 1947, INCLUSIVE

Zones and Segment Numbers				1943			1944			1945			1946			1947			Totals and Averages		
				Number of Borers	Parasites		Number of Borers	Parasites		Number of Borers	Parasites		Number of Borers	Parasites		Number of Borers	Parasites		Number of Borers	Parasites	
0–1	1–3	3–5	5–7		No.	%		No.	%		No.	%		No.	%		No.	%		No.	%
1				185	50	27.0	44	11	25.0	42	7	17.0	52	17	33.0	51	11	21.6	374	96	25.7
	2			50	4	8.0															
	3						41	4	10.0	50	14	28.0	49	27	55.0	49	6	12.2	189	51	26.9
	4			50	13	26.0															
	5						48	7	15.0	35	3	9.0	44	13	29.5	49	12	24.5	176	35	19.8
	6			16	4	25.0															
	7						47	11	23.0	40	10	25.0	45	6	13.0	42	12	28.6	174	39	22.4
	8			50	1	2.0															
	9						24	3	12.5	46	1	2.0	29	1	3.0	51	7	13.7	150	12	8.0
Total for Zone				166	22	13.25	160	25	15.6	171	28	16.4	167	47	28.1	191	37	19.4			
		10		47	12	25.5															
		11								41	4	10.0	28	4	14.0	56	25	44.6	125	33	26.4
		12		37	9	24.0															
		13					27	2	7.0	41	8	19.5	50	27	54.0	21	2	9.5	139	39	28.1
		14		39	3	8.0															
		15					50	3	6.0	43	8	19.0	48	16	33.0	54	2	3.7	195	29	14.9
		16		50	3	6.0															
		17					49	1	2.0	43	4	9.0	53	12	23.0	29	3	10.3	174	20	11.5
		18		50	2	4.0															
		19					20	2	10.0	31	5	16.0	48	12	25.0	22	1	4.5	121	20	16.5
		20		49	2	4.0															
		21								50	4	8.0	42	12	28.5	26	7	26.9	118	23	19.5
		22		50	6	12.0															
		23					52	5	10.0	43	6	14.0	55	7	13.0	36	6	16.7	186	24	12.9
		24		50	0	0															
		25					46	8	17.0	28	3	11.0	47	9	19.0	47	5	10.6	168	25	14.8
Total for Zone				372	37	9.95	244	21	8.6	320	42	13.1	371	99	26.7	291	51	17.5			
			27							24	1	4.0	43	13	30.0	28	4	14.3	95	18	18.9
			29				4	0	0	32	3	9.0	42	11	26.0	25	4	16.0	103	18	17.5
			31				32	1	3.0	42	6	14.0	41	9	22.0	34	2	5.9	149	18	12.1
			33							21	1	5.0	42	14	33.0	46	7	15.2	109	22	20.2
			35				43	4	9.0	43	8	19.0	53	18	34.0	44	4	9.1	183	34	18.6
			37				32	1	3.0	22	0	0	26	16	61.5	51	2	3.9	131	19	14.5
			39				49	4	8.0	37	5	13.5	60	13	22.0	45	8	17.8	191	30	15.7
			41							32	1	3.0	23	0	0	47	20	42.6	102	21	20.6
			43							51	7	14.0	48	14	29.1	37	2	5.4	136	23	16.9
			45				27	5	18.5	53	9	17.0	48	9	19.0	45	9	20.0	173	32	18.5
			47							34	2	6.0	43	24	56.0	46	1	2.2	123	27	21.9
			49				26	9	35.0	30	3	10.0	43	6	14.0	22	2	9.1	121	20	16.5
Total for Zone							213	24	11.3	421	46	10.9	512	147	28.7	470	65	13.8			
Grand Total				723	109	15.1	661	81	12.3	954	123[2]	12.9	1102	316	28.1	1003	164	16.4			

[1]All parasites this species, unless otherwise indicated.

[2]Includes 6 specimens of the native parasite, *Bassus agilis* Cresson.

remarkably consistent, except for 1946. A few highly parasitized collections were responsible for the high average mortality in that year. In four of the 1946 collections, more than half of the borers were killed by parasites. The two most-heavily-parasitized collections recorded during the entire period (61.5 and 56.0 per cent) were made in that year. Oddly enough, these came from the zone five to seven miles from the release point.

In Table IV, data from the Stockley area are arranged with respect to the recovery of parasites at varying distances from the release point. The average rates of parasitism over the five-year period, 1943 to 1947, inclusive, within one, one to three, three to five, and five to seven miles of the release point, were 25.7, 18.5, 15.2, and 16.2 per cent, respectively.

TABLE IV

SUMMARY OF PARASITISM OF EUROPEAN CORN BORER LARVAE BY *Lydella stabulans grisescens* R. D.[1] AT VARYING DISTANCES FROM THE STOCKLEY COLONIZATION POINT, DELAWARE, 1943 TO 1947, INCLUSIVE

MILES FROM COLONIZATION POINT	PERCENTAGE OF PARASITISM FOR SPECIFIED ZONES BY YEARS					AVERAGES
	1943	1944	1945	1946	1947	
1	27.0	25.0	17.0	33.0	21.6	25.7
1 - 3	13.25	15.6	16.4	28.1	19.4	18.5
3 - 5	9.95	8.6	13.1	26.7	17.5	15.2
5 - 7		11.3	10.9	28.7	13.8	16.2
Averages	16.7	15.1	14.3[2]	29.1	18.1	

[1]All parasites this species, unless otherwise indicated.
[2]Includes 6 specimens of the native parasite, *Bassus agilis* Cresson.

Not only was the average for the period higher within one mile of the release point, but each year more parasites were recovered in this than in any of the outer zones.

KIRKWOOD—At Kirkwood (fig. 2), collections of approximately 50 borers were made in the central area and in each of the odd-numbered segments within the concentric circles during the years 1945 to 1947, inclusive. In addition, a collection of 185 borers was made within one mile of the Kirkwood release point in 1943. The data for these four years at this location are presented in Table V and, in Table VI, they are arranged to show rates of parasitism at varying distances from the release point. As at Stockley, *L. stabulans grisescens* was by far the dominant species. A few specimens of other introduced parasites were recovered, including one *M. gifuensis* in 1946 and four, in 1947; also, one *C. annulipes* in 1947. In addition, two specimens of *Pyraustomyia penitalis* Coq., a native form, were reared in 1946.

The number of borers parasitized each year followed the same trend observed at Stockley, with the average parasitism of all zones being 5.6, 23.3, and 14.6 per cent for the years 1945, 1946, and 1947, respectively. In 1945 and 1946, the heaviest parasitism was within one mile of the release point and diminished directly with increasing distance

TABLE V

PARASITISM OF EUROPEAN CORN BORER LARVAE BY *Lydella stabulans grisescens* R. D.[1] AT VARYING DISTANCES FROM THE KIRKWOOD COLONIZATION POINT, DELAWARE, 1943 TO 1947, INCLUSIVE

Zones and Segment Numbers				1943			1945			1946			1947			Totals and Averages		
				Number of Borers	Parasites		Number of Borers	Parasites		Number of Borers	Parasites		Number of Borers	Parasites		Number of Borers	Parasites	
0–1	1–3	3–5	5–7		No.	%		No.	%		No.	%		No.	%		No.	%
1				185	5	2.7	46	4	9.0	46	16	35.0	46	1	2.2	323	26	8.1
	3						50	1	2.0	52	17	33.0	42	1	2.4	144	19	13.2
	5						45	1	2.0	44	1	2.0	52	4	7.7	141	6	4.2
	7						29	5	17.0	31	14	45.0	35	5[3]	14.3	95	24	25.3
	9						40	0	0	50	5	10.0	44	15[4]	34.1	134	20	14.9
Total for Zone							164	7	4.3	177	37	20.9	173	25	14.5			
		11					47	0	0	43	3	7.0	46	22	47.8	136	25	18.4
		13					49	1	2.0	53	3	6.0	51	13	25.5	153	17	11.1
		15					47	1	2.0	48	10	21.0	34	3	8.8	129	14	10.8
		17					50	3	6.0	49	8	16.0	52	7	13.5	151	18	11.9
		19					47	0	0	53	15	28.0	43	5	11.6	143	20	13.9
		21					50	0	0	51	9	18.0	47	4	8.5	148	13	8.8
		23					47	6	13.0	46	15	33.0	39	1	2.6	132	22	16.7
		25					39	3	8.0	54	26	48.0	51	23	45.1	144	52	36.1
Total for Zone							376	14	3.7	397	89	22.4	363	78	21.5			
			27							41	10	24.0	54	13	24.1	95	23	24.2
			35							47	3	6.0	46	6	13.0	93	9	9.7
			37							52	5	10.0	46	4	8.7	98	9	9.2
			39							50	8	16.0	42	1	2.4	92	9	9.8
			41							23	2	9.0	30	18	60.0	53	20	37.7
			43							50	6	12.0	54	1	1.9	104	7	6.7
			45							49	13	26.5	49	4	8.2	98	17	17.3
			47							54	1	2.0	51	13	25.5	105	14	13.3
			49							42	14	33.0	52	26	50.0	94	40	42.5
Total for Zone										408	62	15.2	424	86	20.3			
Grand Total				185	5	2.7	586	25	4.3	1028	204[2]	19.8	1006	190	18.9			

[1]All parasites this species, unless otherwise indicated.
[2]Includes 1 *Macrocentrus gifuensis* and 2 *Pyraustomyia penitalis*.
[3]Includes 4 *Macrocentrus gifuensis*.
[4]Includes 1 *Chelonus annulipes*.

from that point. In 1947, however, this relationship was reversed, with a rate of 2.2 per cent at the release point and of 20.3 per cent in the zone five to seven miles distant.

TABLE VI

SUMMARY OF PARASITISM OF EUROPEAN CORN BORER LARVAE BY *Lydella stabulans grisescens* R. D.[1] AT VARYING DISTANCES FROM THE KIRKWOOD COLONIZATION POINT, DELAWARE, 1945 TO 1947, INCLUSIVE

MILES FROM COLONIZATION POINT	PERCENTAGE OF PARASITISM FOR SPECIFIED ZONES BY YEARS			AVERAGES
	1945	1946	1947	
1	9.0	35.0	2.2	15.4
1 - 3	4.3	20.9	14.5[2+4]	13.2
3 - 5	3.7	22.4	21.5	15.8
5 - 7	....	15.2	20.3	17.7
Averages	5.6	23.3[3]	14.6	

[1]All parasites this species, unless otherwise indicated.
[2]Includes 1 *Macrocentrus gifuensis* and 2 *Pyraustomyia penitalis*.
[3]Includes 4 *Macrocentrus gifuensis*.
[4]Includes 1 *Chelonus annulipes*.

TABLE VII

PERCENTAGE OF EUROPEAN CORN BORER LARVAE PARASITIZED BY *Lydella stabulans grisescens* R. D.[1] AT SEVEN RELEASE POINTS IN DELAWARE, 1945 AND 1946

LOCATION	1945			1946		
	Number of Borers	Parasites		Number of Borers	Parasites	
		Number	Per Cent		Number	Per Cent
Hockessin	176	7[2]	4.0	201	37[4]	18.4
Townsend	162	43	26.5	153	37[5]	24.2
Dover	164	4	2.4	185	19	10.3
Frederica	151	6	4.0	179	31[6]	17.3
Farmington	176	0	0.0	143	19[7]	13.3
Milton	159	19[3]	12.0	188	37[8]	19.7
Laurel	163	5	3.1	195	49	25.1
Totals	1151	84	7.3	1244	229	18.4

[1]All parasites this species, unless otherwise indicated.
[2]Includes 3 *Macrocentrus gifuensis*.
[3]Includes 1 *Macrocentrus gifuensis*.
[4] Includes 19 *Macrocentrus gifuensis*.
[5]Includes 1 native parasite, *Cremastus minor*.
[6]Includes 1 native parasite, *Pyraustomyia penitalis*.
[7]Includes 1 *Macrocentrus gifuensis*.
[8]Includes 6 *Macrocentrus gifuensis*.

ADDITIONAL RELEASE POINTS IN THE STATE—In Table VII, data are presented on borer parasitism at seven of the nine original liberation sites (the remaining two sites are recorded under Stockley and Kirkwood). At each of these locations, an attempt was made to secure 200 larvae for processing during the years 1945 and 1946.

Most of the parasites recovered were *L. stabulans grisescens*, but *M. gifuensis* equalled this species in material from Hockessin. Also, it was present in some of the collections from each county, indicating that it has become established. One each of the native parasites, *Cremastus minor* Cush. and *P. penitalis*, were reared.

In the two-year period, only the 1945 collections from Farmington failed to yield parasites. That the parasites became established at this point was indicated by the collection for the following year, when 13.3 per cent of the borers were destroyed. In 1945, 26.5 per cent of the Townsend collection was parasitized. This was more than twice the rate obtained at any other location.

The average parasitism in 1945 for the seven areas was 7.3 per cent. The following year, there was a rise in the number of borers destroyed by parasites. At all locations, more than 10 per cent of the borers were killed.

TABLE VIII

PERCENTAGE OF EUROPEAN CORN BORER LARVAE PARASITIZED BY *Lydella stabulans grisescens* R. D., SUPPLEMENTARY COLLECTIONS AT 10-MILE INTERVALS FROM CLAYMONT TO REHOBOTH, DELAWARE, 1945

County and Collection Number	Number of Borers	Parasites	
		Number	Per Cent
New Castle— 1	56	6	10.7
2	55	0	0
3	64	3	4.7
4	45	7	15.6
Kent — 5	41	0	0
6	54	0	0
7	30	0	0
Sussex — 8	52	4	7.7
9	52	2	3.8
10	65	3	4.6
Totals	514	25	4.9

SUPPLEMENTARY COLLECTIONS—*L. stabulans grisescens* was present in six of the 10 supplementary collections (Table VIII and fig. 4). The average parasitism was 4.9 per cent. One collection from New Castle County was negative for parasites, as were all those taken in Kent County. Each of the three collections from Sussex County contained parasites.

STATE-WIDE PARASITE RECOVERIES—In 1947, a survey based on 10-mile-square sections superseded the collections made in previous years at the seven parasite-colonization-sites mentioned above. The divisions of the State and the percentage of borers killed by parasites are shown in figure 5. It is believed that an adequate sample of the distribution and density of the parasite population in the State was obtained by this method.

Table IX presents the data on the extent of parasitism of borer larvae. With the exception of one specimen of *M, gifuensis* reared from the vicinity of Hockessin, all data refer to *L. stabulans grisescens.*

The average parasitism of borer larvae in the three counties was very uniform—11.2, 11.4, and 11.9 per cent, for New Castle, Kent, and Sussex, respectively. The highest rate was recorded near Bridgeville, where 32.1 per cent of the borers were destroyed.

TABLE IX

PARASITISM OF EUROPEAN CORN BORER LARVAE BY *Lydella stabulans grisescens* R.D.[1] IN 10 X 10-MILE SECTIONS, STATE-WIDE SURVEY, DELAWARE, 1947

SECTION NUMBER	NUMBER OF BORERS	PARASITES		EMPTY PUPARIA RECORDED
		Number	Per Cent	
1	51	8[2]	15.7	20
2	35	1	2.9	2
3	44	9	20.5	7
4	51	2	3.9	7
5	53	5	9.4	14
6	56	6	10.7	11
7	28	3	10.7	7
8	48	7	14.6	6
New Castle Co.	366	41	11.2	74
9	35	3	8.6	12
10	41	1	2.4	6
11	38	11	28.9	19
12	51	1	2.0	8
13	47	0	0.0	2
14	47	8	17.0	6
15	53	9	17.0	7
16	47	8	17.0	22
Kent Co.	359	41	11.4	82
17	40	5	12.5	8
18	52	13	25.0	14
19	56	18	32.1	14
20	41	3	7.3	9
21	45	2	4.4	8
22	50	9	18.0	9
23	44	3	6.8	6
24	47	6	12.8	4
25	44	2	4.5	8
26	51	2	3.9	10
27	48	4	8.3	8
28	50	4	8.0	14
29	44	3	6.8	8
30	44	4	9.1	6
Sussex Co.	656	78	11.9	126
Totals	1381	160	11.5	282

[1]All parasites this species, unless otherwise indicated.
[2]Includes 1 *Macrocentrus gifuensis.*

Parasites were reared from all but one of the 30 collections. However, there is evidence that *L. stabulans grisescens* was present at that location as well. In the course of the survey, records were kept of empty *L. stabulans grisescens* puparia found in the dissected stalks. These are shown in the last column of Table IX. Empty puparia were found at all

collection points. Actually, they outnumbered the total parasites reared—282 empty puparia were found; only 160 parasites were reared from borer larvae. However, it is likely that these puparia are the residue of more than one brood and, thus, cannot be added to, or compared with, the total parasites reared from borers.

The data presented are conclusive evidence that the spread of *L. stabulans grisescens*, since its original introduction in 1941, has been state-wide in character.

During the course of these studies, no record was obtained of hyperparasites attacking *L. stabulans grisescens*.

SUMMARY

A total of 97,156 European corn borer parasites representing five species—*Macrocentrus gifuensis* Ashm., *Eulophus viridulus* Thoms., *Horogenes punctorius* Rom., *Lydella stabulans grisescens* R. D., and *Chelonus annulipes* Wesm.—have been liberated in Delaware during the years 1941 to 1946, inclusive.

Information on the extent of parasitism was obtained by collecting full-grown borer larvae in the fall and early winter. These collections were made in the vicinity of the parasite release points and, in 1947, at 30 locations selected systematically so as to cover the entire State. In addition, collections were made in special study-areas established about two of the colonization sites to secure data on parasite dispersal.

Of the five species of parasites released, three—*L. stabulans grisescens*, *M. gifuensis*, and *C. annulipes*—are known to have become established. *M. gifuensis* has been reared from Hockessin, Farmington, and Milton, although it was of importance only at Hockessin. *C. annulipes* was recovered from Kirkwood alone. *L. stabulans grisescens* appears to be of considerable value throughout the State in reducing the number of overwintering borers. Studies at Stockley and Kirkwood indicate that the spread of this tachinid has been outward in all directions from the point of liberation. The average rate of parasitism for all collections at Stockley ranged from 9.95 per cent in 1943 to 28.7 per cent, in 1946. Two of the collections at this location showed in excess of 55 per cent of the borers killed by this fly. The parasitism at Kirkwood also showed an increase of from 2.7 per cent borers killed in 1943, to 19.8 per cent destroyed in 1946. Likewise, collections from the remaining seven liberation sites provided an increased parasitism rate, from 7.3 per cent in 1945 to 18.4 per cent in 1946.

In the 1947 collections designed to show parasite conditions in 30 areas throughout the State, *L. stabulans grisescens* was present in all but one. The percentage of borers killed was remarkably consistent for each county—New Castle, 11.2 per cent; Kent, 11.4 per cent; and Sussex, 11.9 per cent—or an average of 11.5 per cent for the State as a whole.

Certain native parasites—*Bassus agilis* Cresson, *Cremastus minor* Cush., and *Pyraustomyia penitalis* Coq.—were reared, but in insignificant numbers.

During the course of these studies, no record was obtained of hyperparasites attacking *L. stabulans grisescens*.

VITAMIN REQUIREMENTS OF THE COCKROACH BLATELLA GERMANICA (L.)[1]

JERRE L. NOLAND, J. H. LILLY,[2] AND C. A. BAUMANN,
Departments of Biochemistry and Economic Entomology,
College of Agriculture, University of Wisconsin

The nutrition of the German cockroach, *Blattella germanica* (L.), was first studied by Zabinski (1928, 1929) who observed that these insects required "vitamin B" but that they could grow fairly well on diets inadequate for vertebrates. Somewhat later McCay (1933) suggested that this species be used as an assay animal for certain "vitamin B" fractions. Semi-synthetic diets were employed by Melampy and Maynard (1937) in a general survey of the requirements of this species. Recently a method of rearing the German cockroach has been developed which enables it to be used for quantitative studies of dietary requirements (Noland *et al*, 1949). By use of this procedure, it has become possible to determine specific requirements of the cockroach for various dietary components. The present paper describes a synthetic diet on which the growth rate of *B. germanica* equals or exceeds that on the best crude diet known. By suitable variations of this diet the effects of 11 single vitamin deficiencies on the growth of *B. germanica* have been determined. Preliminary comparisons have also been made of the growth responses of *Periplaneta americana* (L.) and *Blatta orientalis* (L.) when fed a synthetic diet and a crude diet.

MATERIALS AND METHODS

The insects used in these experiments were from four inbred strains previously described (Noland *et al*, 1949). With inbreeding these strains have tended to become more uniform in growth response. The feeding experiments with *B. germanica* were conducted in the standard wire-screened rearing tubes described previously, while the nymphs of *P. americana* and *B. orientalis* were reared in the over-size modification of the standard rearing cage (Noland *et al*, 1949). The cages were kept in the ante-room to a 37°C. incubator, where the temperature averaged about 30°C. (27–32°C. range). In early experiments the nymphs were weighed at various ages, but later they were weighed at 10, 20 and 30 days, respectively. The average age at maturity was recorded for each group. Some groups were saved after maturity for observations of their reproductive performances.

The synthetic diets were prepared in three parts and mixed as follows. The casein and salt mixture was first ground in a Wiley mill to

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[2]Now Professor of Zoology and Entomology, Iowa State College.

pass a 100-mesh screen, then further pulverized in a ball mill for 24 hours, and the carbohydrate added. The vitamins that were common to a series of synthetic diets were weighed out and dissolved in water. Three ml. of this vitamin solution were added to 20-gram portions of the dry ingredients. Additional solutions of single vitamins were added to specific diets as needed, and the moist ration mixed in a mortar until uniform, then spread on paper to dry at room temperature. The fat and cholesterol were dissolved in 3-ml. portions of chloroform, and stirred into the dried mixtures in a mortar. The diets were spread out to dry as before, then stored in a refrigerator. The food and water in the cages were replaced weekly. For each series of synthetic diets to be tested, the day-old nymphs from one egg-sac were divided among eight groups with about five nymphs to a cage. Usually seven of the groups received different experimental diets while the remaining group received a crude diet (dog biscuits) or the best synthetic diet available.

Riboflavin was determined by a microbiological method, with *Lactobacillus casei* as the assay organism and medium IV of Sauberlich and Bauman (1946), modified by the omission of riboflavin. Each group of insects to be analyzed was weighed, then homogenized in a Potter-Elvehjem motor-driven homogenizer with 5 ml. of 0.1 N H_2SO_4. The homogenate was autoclaved at 15 pounds pressure for 15 minutes, neutralized with NaOH to pH 6.8, diluted to 25 ml. and then filtered. Varying aliquots of this sample were added to the basal medium and incubated at 37° for 72 hours, and the amount of acid produced was determined by titration. The standard curve covered the range 0 to 0.05 micrograms of riboflavin.

RESULTS

Synthetic Diets I and II.—The composition of two fairly satisfactory synthetic diets, designated as synthetic diets I and II, has been described previously (Noland *et al*, 1949). By using these diets as standards the requirements of roaches for the various nutrients were estimated by omitting or altering the percentage composition of single ingredients.

The growth of roaches fed different carbohydrates was determined with synthetic diet I (Table I). Dextrin (coarsely ground) promoted the fastest rate of growth, with glucose, sucrose, lactose and starch following in decreasing order (Table II). In later experiments when finely-ground dextrin was fed there was a marked decrease in the rate of growth, which became no better than when starch was fed. This apparent effect of particle size suggested that the use of coarsely ground dextrin permitted a preferential selection of other components of the diets by the nymphs. Accordingly, varying amounts of an indigestible substance (*Cellu Flour*) were added to synthetic diet II (Table I). The best rate of growth was observed when the level of *Cellu Flour* was 30 per cent of the diet, added at the expense of the carbohydrate. On this diet the *Cellu Flour* effectively increased the relative concentration of protein, salts, fat and vitamins ingested.

When a diet similar to synthetic diet I was used as a standard, and the percentage of alcohol-extracted casein in the diet was varied, the growth response was found to be greatest on the diet containing 30 per cent of casein. Decreased growth rates were observed at levels of

45, 20, 15, and 10 per cent of dietary casein (Table II). The omission of cystine from synthetic diet I caused no decrease in the growth rate.

The amount of corn oil in diet I has been varied through levels 0, 1, 2, 3, 5, and 10 per cent, at the expense of the carbohydrate. A level of 3 per cent was found to be the most favorable amount tried. The cholesterol content of diet I was varied progressively from 0 to 2

TABLE I

COMPOSITION OF SYNTHETIC DIETS

COMPONENT	SYNTHETIC DIET NO.			
	I	II	III	IV
	Parts			
Glucose monohydrate (*Cerelose*)	74	62	32	32
Casein ("vitamin-free")	15	30	30	30
Cellu Flour[1]			30	30
Wesson's salt mixture[2]	4	4	4	4
Corn oil	5	3	3	3
Cholesterol	1	1	1	1
L-Cystine	0.6			
Vitamin mixture	0.3	0.3	0.4	0.6
	Micrograms/gram			
Chorine Cl	1000	1000	2000	4000
Thiamine	12	12	12	12
Riboflavin	18	18	18	18
Nicotinic acid	100	100	100	100
Calcium pantothenate	40	40	40	40
Pyridoxine	16	16	16	16
Inositol	2000	2000	2000	2000
p-aminobenzoic acid	50	50	50	50
Biotin	0.6	0.6	0.6	0.6
Folic acid	5	5	5	5
Vitamin K. (*Menadione*)	1	1	1	1

[1]Manufactured by Chicago Dietetic Supply House, Chicago, Ill.
[2]Wesson, L. G., Science, 75: 339 (1932).

per cent (Table II), with the best growth response observed when 1 per cent of the diet was cholesterol.

The salt mixture employed (Wesson, 1932) has frequently been used by others in diets for mice and rats, and appears to contain all of the mineral elements needed by higher animals. Attempts to reduce the level of this particular salt mixture from 4 per cent to 2, 1, and 0.5 per cent, respectively, in synthetic diet I resulted in a decreased rate of growth of the roaches. It is conceivable, however, that a salt mixture

compounded especially for roaches might be adequate at a level below 4 per cent.

When the level of choline in synthetic diet II was increased from 1000 to 2000 γ/gm. the rate of growth increased somewhat. This change, combined with the inclusion of 30 per cent of *Cellu Flour* as bulk at the expense of the carbohydrate, resulted in the formulation of synthetic diet III. The composition of this diet is given in Table I.

Synthetic diet III.—The results of five experiments in which dog biscuits and synthetic diet III were both fed to nymphs hatching from

TABLE II

EFFECT OF DIETARY CARBOHYDRATE, PROTEIN AND CHOLESTEROL ON GROWTH AND MATURITY OF *B. germanica* FED SYNTHETIC DIET I

DIET		WEIGHT IN MG.			MATURITY IN DAYS		SURVIVAL (FRACTION)
Component	Per Cent				Aver.	Range	
		12 days	30 days	44 days			
Carbohydrate							
Glucose[1]	74[2]	5	24	43	53	47–58	5/5
Sucrose	74	4	21	41	55	42–77	5/6
Dextrin (coarse)	74	6	30	53	51	49–53	6/6
Starch	74	3	12	17	100	92–128	4/6
Lactose	74	4	21	31	62	58–71	5/6
		15 days	30 days				
Protein							
Casein	10	6	8	.....	(dead)	.....	0/7
Casein	15[2]	7	17	.....	66	59–76	4/7
Casein	30	13	35	.....	45	41–52	5/7
Casein	45	10	29	.....	48	43–51	6/7
		11 days	29 days	43 days			
Sterol							
Cholesterol	0[3]	4	13	21	68	57–72	4/6
Cholesterol	0.001	4	12	23	70	56–82	5/6
Cholesterol	0.01	4	13	24	70	64–73	5/6
Cholesterol	0.1	5	21	36	58	49–80	5/6
Cholesterol	1.0[2]	5	22	35	57	52–64	6/6
Cholesterol	2.0	5	22	38	55	48–64	6/6

[1]Glucose monohydrate, known commercially as "Cerelose."
[2]Amount of component present in synthetic diet I.
[3]Corn oil contains some sterols which may have been sufficient to support growth at low levels of added cholesterol.

the same egg-sacs are given in Table III. In every case the growth rate of the nymphs fed synthetic diet III was greater than the growth rate of those receiving dog biscuits, although growth and maturation on the latter diet were at least as good as that recorded previously (Noland *et al*, 1949). Furthermore the nymphs fed the synthetic diet matured sooner than corresponding groups fed dog biscuits (Table III).

In a further evaluation of the biological value of synthetic diet III, groups of adults maturing on this diet, or on variations of it that permitted equivalent growth, were saved for a period of 40 days after maturity, and their reproductive performance compared with that of roaches fed dog biscuits. In contrast to the sustained high growth rate, fertility, and vigor of roaches reared on dog biscuits for eight successive generations, the reproductive performance of the insects reared on synthetic diets was generally unsatisfactory. The egg-sacs

TABLE III

COMPARISON OF GROWTH RATE AND RATE OF MATURATION OF *B. germanica* FED SYNTHETIC DIET III AND DOG BISCUITS

EXPERIMENT	WEIGHT IN MG.			MATURITY IN DAYS		SURVIVAL (FRACTION)
	10 days	20 days	30 days	Aver.	Range	
	Growth on Synthetic Diet III					
A	.....	22	45	38	37–40	6/6
B	6	23	40	39	37–41	4/4
C	5	19	34	43	39–46	4/5
D	7	31	69	33	31–36	5/5
E	8	.....	54	35	33–39	5/5
Average	6.5	23.8	48.4	37.6		
	Growth on Dog Biscuits[1]					
A	.....	20	36	41	40–42	5/5
B	6	20	48	39	39–40	3/3
C	5	17	32	44	42–45	3/3
D	6	26	51	36	32–40	3/4
E	7	.....	67	36	33–37	5/5
Average	6.0	20.8	46.8	39.2		

[1] *Friskies* Brand. Manufactured by Albers Milling Co., Peoria, Illinois.

from roaches grown on the synthetic diets were often small, deformed or shriveled. Some were discolored by transverse dark bands, while others were abnormally light in color; many were eaten by the adults. Only a small proportion of the egg-sacs produced live nymphs. When hatching occurred, the number of live nymphs per egg-sac was never greater than 30, and in many cases was only 2 or 3, as compared to a normal of 40. The nymphs were often too weak to walk, and many were eaten by the adults. Furthermore, the growth rate of these nymphs was usually slower than normal. In order to test this effect quantitatively, two hatchings of these nymphs were divided among 10 cages and fed various synthetic diets. As controls, two hatchings of

TABLE IV

EFFECTS OF SINGLE VITAMIN DEFICIENCIES ON GROWTH AND MATURITY OF *B. germanica* FED SYNTHETIC DIET III

VITAMIN OMITTED	EXPERIMENT[1]	WEIGHT IN MG.			MATURITY IN DAYS		SURVIVAL (FRACTION)
		10 days	20 days	30 days	Aver.	Range	
None (Diet III)	A	6	23	40	39	37–41	4/4
"	A	8	22	57	39	38–41	5/5
"	B	6	19	.....	41	40–43	5/5
"	C[2]	.....	20	38	43	34–51	5/5
"	D	5	18	39	40	39–41	5/5
"	E	10	22	45	40	31–44	5/6
Choline Cl	A	4	3	Dead	.....	.....	0/5
"	F	3	4	Dead	.....	.....	0/6
Ca Pantothenate	B	3	4	Dead	.....	.....	0/5
"	D	5	16	19	Dead	.....	0/5
"	E	4	4	4	Dead	.....	0/6
Nicotinic Acid	A	4	6	6	Dead	.....	0/5
"	D	4	14	22	Dead	.....	0/5
"	E	4	5	6	Dead	.....	0/6
Pyridoxine	B	5	20	.....	44	40–54	4/5
"	D	5	18	34	53	42–63	2/6
"	E	11	16	22	Dead	.....	0/6
Thiamine	A	6	12	19	64	51–78	2/5
"	D	4	17	38	40	39–43	5/5
"	E	6	9	20	48	.....	1/6
Riboflavin	B[2]	6	19	.....	41	38–44	5/5
"	D	5	19	36	50	39–59	4/6
"	E	8	15	30	49	42–54	3/6
Inositol	A	9	24	47	38	34–41	5/5
"	C	.....	14	28	45	40–52	5/5
PAB	A	6	21	44	38	34–41	4/5
"	C	.....	20	38	43	41–47	5/5
Menadione	B	5	21	.....	39	38–40	5/5
"	C	.....	19	31	48	44–53	5/5
Biotin	B	5	19	.....	41	38–43	6/6
"	D	5	18	37	40	37–42	6/6
"	E	11	19	32	44	38–55	3/6
Folic Acid	B	6	25	.....	36	36–37	6/6
"	D	5	19	36	40	35–42	6/6
"	E	11	26	51	34	32–37	6/6

[1]In experiment D, nymphs three days of age were used; in all the other experiments one-day-old nymphs were used.

[2]Groups of insects analyzed for riboflavin (Table V).

nymphs from adults reared on dog biscuits were fed the same diets. Both the growth rate and life span of the experimental groups were only about half those of the control groups. It was therefore obvious that synthetic diet III was not adequate for the roach throughout its life cycle. Nevertheless, the fact that the diet permitted rates of growth and maturation that exceeded the best hitherto observed on crude diets has made synthetic diet III very useful in determining the role of specific nutrients in the roach.

Effect of single vitamin deficiencies.—With synthetic diet III as a control, roaches were fed a series of diets from which each of the B-vitamins was omitted singly, and all pertinent experiments were repeated at least once. The growth and maturation of roaches on these diets are shown in Table IV. As a result of these experiments the relative effects of single vitamin deficiencies may be divided into three classes. The critical vitamins appear to be choline, pantothenic acid and nicotinic acid. When any one of these vitamins was omitted from the diet, the rate of growth was drastically reduced and none of the roaches reached maturity. Such nymphs often died within the first month of life. However, in a single series, (Table IV, experiment D), nymphs that had access to dog biscuits for 3 days after hatching and prior to the feeding of the deficient diets grew moderately well on diets lacking nicotinic acid and calcium pantothenate, and their life span was prolonged in comparison with that of nymphs fed the incomplete diets from the day of hatching. Nevertheless, the growth rate of these 3-day old nymphs was much slower than that of "litter-mates" fed other synthetic diets, and they never reached maturity (Table IV).

Three vitamins which were limiting for growth when omitted from diet III, but which did not appear to be necessary for maturity, were pyridoxine, thiamine and riboflavin. When any one of these vitamins was omitted, individual variations in growth rate and maturity were marked, the average growth rate becoming considerably less than that of nymphs fed the complete diet. Some individual insects matured at the normal rate, while others died before maturation (Table IV).

The vitamins which caused no consistent decrease in growth rate and no increase in mortality when omitted singly included inositol, PAB, menadione, biotin, and folic acid. In some series of experiments in which these vitamins were omitted, the growth rate was as good as that on the control synthetic diet. In some cases, e.g., when folic acid was omitted in experiments B and E, maturity was reached sooner than when the control diet containing this vitamin was fed.

Since the omission of a single vitamin often exerted quite variable effects upon the growth rates of different insects in the same group, the question arose whether some of the vitamins were being synthesized in the insects. This possibility was examined in the case of riboflavin, a vitamin which is critical in the diets of higher animals but which, when omitted from the diet of the German roach caused only an irregular decrease in growth rate (Table IV). Determinations were made of the riboflavin content of roaches fed dog biscuits, synthetic diet III or synthetic diet III with riboflavin omitted; newly-hatched nymphs and the "vitamin-free" casein were also analyzed. The results of these analyses are presented in Table V.

Newly-hatched nymphs from stock females fed dog biscuits were found to contain an average of 3.9 γ per gram, or about 0.007 γ riboflavin per insect. When reared on a "riboflavin-free" synthetic diet, the adults contained an average of 3.0 γ per gram, or about 0.2 γ per insect. This indicates that each insect accumulated an average of 0.2 γ riboflavin during its life. Analysis of the casein used[2] showed that it contained 0.25 γ of riboflavin per gram. Calculation shows that each insect fed the "riboflavin-free" diet would have had to ingest 0.8 grams of the casein, or about 2.9 grams of the diet to supply all the riboflavin present in their bodies at the time of analysis. This amount of diet is approxi-

TABLE V

EFFECT OF DIET ON THE RIBOFLAVIN CONTENT OF *B. germanica*

INSECTS ANALYZED				RIBOFLAVIN CONTENT OF FRESH TISSUE	
Number	Sex	Age	Diet	γ/gram	γ/insect
123	(Nymphs)	1 day	Dog Biscuits	3.8 4.1 3.9	0.007 0.007 0.007
8 2	Females Males	54 days	Dog Biscuits	7.0 7.2 6.8	0.49 0.50 0.48
2	Males	90 days	Diet III	19.7 18.8	1.15 1.10
2	Females	90 days	Diet III	12.9 11.9	1.39 1.28
1 4	Female Males	90 days	Diet III (riboflavin omitted)	3.2 2.8 3.0	0.23 0.20 0.22
			Casein used in all synthetic diets	0.20 0.27 0.27	

mately 50 times the body weight of each adult insect. It is, therefore, highly probable that riboflavin had been synthesized by the roach or by microorganisms associated with it.

Growth of other species of cockroaches on a synthetic diet.—Since synthetic diet III had proved superior to the best crude diet available for the growth of *B. germanica*, a similar diet, synthetic diet IV (Table I) was fed to nymphs of two other common species of roaches, *Periplaneta americana* (L.) and *Blatta orientalis* (L.), for comparison with the German roach. The day-old nymphs hatching from one egg-sac were

[2]This casein had been extracted with alcohol and with dilute acetic acid. The content of riboflavin found is comparable with the value of 0.26 γ riboflavin/gram for acid-washed casein reported by Cannon *et al* (1945).

divided into two groups, which were fed dog biscuits or synthetic diet IV, respectively. The nymphs in each cage were weighed at 10-day intervals. The growth curves for these nymphs are presented in Figure 1, in comparison with growth curves for *B. germanica* on the same diets. The growth rate of *B. germanica* was much faster when diet IV was fed than when a diet of dog biscuits was used. *B. orientalis* grew at least as well on the synthetic diet as on the crude diet, and *P. americana* grew considerably better on the synthetic diet.

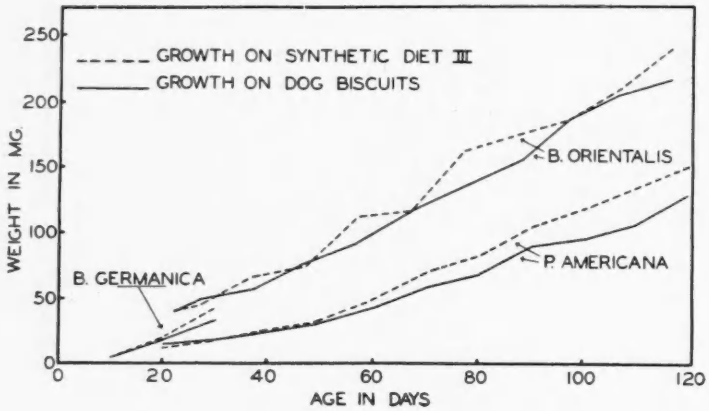

FIGURE 1. Growth of three species of cockroaches fed dog biscuits and synthetic diet III respectively.

DISCUSSION

The growth rates of the three species of cockroaches used in these experiments were considerably faster than those reported by others who have studied the nutrition of these species. Melampy and Maynard (1937) reported that the German roach required 42 days to attain a weight of 46 mg.; in comparison, in these experiments this weight was attained in only 30 days (Table III). Gould (1940) reported an average age at maturity of 74 days for this species, as compared with 39 days in these experiments (Table III). Using the American roach, Gier (1947) obtained a weight of 50 mg. at 100 days, as compared with 96 mg. in these experiments at the same age (Fig. 1). Recent growth data on the Oriental roach are not available for comparison.

In general, insects have not been reared as successfully on highly purified diets as on crude diets. The exceptions include the clothes moth, *Tineola bisselliella* Hum., which grew more rapidly on a highly purified diet than on the best natural diet tried (Fraenkel and Blewett, 1946a). Comparable rates of growth on purified and crude diets have been reported for the beetles *Tribolium confusum* Duv., *Ptinus tectus* Boield., *Sitodrepa panicea* L., and *Lasioderma serricorne* Fab. (Fraenkel

and Blewett, 1943). The three species of cockroaches used in the present experiments all grew faster on the purified diet than on the best crude diet tried. These species of insects are therefore added to the list of laboratory animals which may be grown successfully, and at a rapid rate of growth, under rigidly defined conditions.

The reduced ability of the cockroaches to reproduce when fed the synthetic diets could not be traced to a deficiency of any known ingredient of the diet, nor did there appear to be a good correlation between the ability of any particular synthetic diet to support growth and reproduction. This suggests the possibility that the synthetic diets may be deficient in a "reproduction factor" supplied by the dog biscuits. Grison (1947) has postulated the existence of a "fertility factor" for the potato beetle, *Leptinotarsa decemlineata* Say, which is found in fresh potato leaves but not in older leaves.

The relative essentiality of the B vitamins for the German roach is similar to, but not identical with, that of other species of insects, but it differs greatly from that of the rat, chick, and other higher animals which have been studied. Choline, the most critical vitamin for the cockroach, had previously been found by Fraenkel and Blewett (1943) to be the most essential vitamin for *Lasioderma*. However, choline did not appear to be critical for any of the other species studied by Fraenkel and Blewett, although its omission often resulted in a decreased rate of growth. In the present experiments roaches grew very poorly on the synthetic diets containing only 500 micrograms/gram of choline Cl, which was the level uniformly employed by Fraenkel and Blewett in their synthetic diets for other species of insects. Furthermore, improved growth was observed with the German roach when increased levels of choline up to 4000 micrograms/gram in diet III were fed.

Pantothenic acid and nicotinic acid, which were necessary for the roach to reach maturity, were found to be essential for normal pupation of *Tineola* (Fraenkel and Blewett, 1946a), and to be necessary for the optimal growth of several other species of beetles (Fraenkel and Blewett, 1943). Pyridoxine, thiamine and riboflavin, which were necessary for good growth and survival of the German roach, but not necessary for maturity, are generally listed as being growth-promoting for insects (Trager, 1947). The finding that the omission of inositol, PAB, biotin, and vitamin K caused little or no decrease in growth rate of the cockroach is also in accord with the work of others. The fact that omission of folic acid sometimes caused an increase in the rate of growth of cockroaches has not been explained.

The indication that German roach nymphs maturing on a low-riboflavin diet accumulated more riboflavin than could be obtained merely by ingesting the diet indicates that riboflavin must have been synthesized in the insect. It is suggested that this synthesis is due to the action of microorganisms inhabiting the digestive tract. This conclusion is in accord with the observation by Busnel and Drilhon (1943) that riboflavin was produced in the gut of *Tineola* fed a riboflavin-free diet, and also with the conclusion of Fraenkel and Blewett (1946b) that the synthesis of vitamins occurs in the intestine of insects. Metcalf and Patton (1942), however, state that there is little or no synthesis of riboflavin in the American roach.

SUMMARY

1. A basic synthetic diet is described on which three common species of cockroaches grew faster than on dog biscuits, the best crude diet tested. However, reproduction by roaches fed this synthetic diet was inferior to that of insects fed dog biscuits.

2. The requirements of *B. germanica* for the B vitamins was studied by the omission of each vitamin singly from the synthetic diet. The omission of choline, pantothenic acid and nicotinic acid resulted in extremely slow growth, and death before maturity was reached. The omission of pyridoxine, thiamine and riboflavin resulted in retarded but significant growth, and increased mortality with some insects reaching maturity. The omission of inositol, PAB, manadione (vit. K), or biotin usually had no adverse effect upon growth rate or survival, while the omission of folic acid from the diet seemed to stimulate growth somewhat.

3. German roaches reared on a synthetic diet extremely low in riboflavin accumulated more of this vitamin than was present in the diet they ingested. It is suggested that this vitamin was synthesized by intestinal microorganisms.

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BLOOD VOLUME AND CHLORIDE NORMALITY IN ROACHES (PERIPLANETA AMERICANA (L.)) INJECTED WITH SODIUM CHLORIDE SOLUTIONS

SAM C. MUNSON[1] AND J. FRANKLIN YEAGER,[1]

U. S. Department of Agriculture, Agr. Res. Adm., Bureau of Entomology and Plant Quarantine

The results of the determination of blood volume in the American cockroach, *Periplaneta americana* (L.), reported in another paper (2), gave rise to the question—What changes would blood volume and blood chloride undergo if roaches were injected with different concentrations of sodium chloride solution? Partial answers to this and certain other questions are provided by experiments reported here, in which blood volume[2] and total chloride[3] in American roach nymphs were measured at different time intervals after they had been injected with different concentrations of sodium chloride solution. The results support the suggestion made previously in a study of the mode of insecticidal action of sodium metarsenite (3), that the injection of a higher concentration of sodium chloride into a roach would favor the retention of more water by the blood.

METHODS AND RESULTS

Groups of 10 nymphs (mixed sexes) were used. All nymphs in a group were injected with the same concentration of sodium chloride dissolved in distilled water, but different groups received different concentrations. At a selected interval after injection (the interval differing with the different groups of insects) each insect was heat-fixed and its blood volume determined by the dye method (2). Each roach that had been injected with 5 N sodium chloride received 10 μ L. per gram of body weight of the dye-saline solution; all others received 20 μ L. Each group of dye-injected roaches then was divided into two subgroups of 5 each (or 4 in cases where a roach showed hemorrhage and was discarded). Blood samples from each member of a subgroup were pooled and titrated for chloride, as described elsewhere (2). Thus, for each group of 10 insects, 10 individual blood-volume determinations and two chloride titrations of pooled blood were made at the proper time interval after injection.

The concentrations of sodium chloride injected ranged from zero (distilled water) to 5 N. Distilled water was injected in only one group

[1]S. C. Munson is now assistant professor of biology, George Washington University, and J. F. Yeager is now with the Division of Research Grants and Fellowships, National Institute of Health, Bethesda, Maryland.

[2]In this paper, unless otherwise specified, blood volume will refer to the number of μL. of blood in an insect and blood volume percent will refer to blood volume in μL. divided by body weight in milligrams. One μL. equals 0.000001 liter.

[3]The chloride normalities referred to in this paper were measured by an adaptation of the titration method of Mohr (2).

TABLE I

BLOOD-VOLUME PERCENT AND BLOOD-CHLORIDE NORMALITY OF AMERICAN ROACHES AT VARIOUS TIMES AFTER INJECTION WITH DIFFERENT CONCENTRATIONS OF SODIUM CHLORIDE

CONCENTRATION OF NaCl	0 MINUTES		30 MINUTES		60 MINUTES		120 MINUTES		240 MINUTES		360 MINUTES		ca. 1400 MINUTES	
	Blood-volume percent[1]	Chloride[1]	Blood-volume percent	Chloride	Blood-volume percent	Chloride	Blood-volume percent	Chloride	Blood-volume percent	Chloride	Blood-volume percent	Chloride	Blood-volume percent	Chloride
10.00	21.5	0.562	46.3	0.301	.....	.....	.....	.....	41.2	0.305	.....	.....	.....	.....
8.00	21.5	.477	38.0	.277	36.4	0.289	39.2	0.276	36.6	.287	36.6	0.283	.....	.....
6.00	21.5	.392	39.8	.254	40.0	.262	40.0	.274	35.6	.262	36.0	.260	.....	.....
5.00	20.5	.372	39.4	.253	38.8	.231	39.3	.242	31.7	.224	26.0	.255	.....	.....
4.00	20.5	.320	37.1	.223	34.4	.196	39.2	.197	31.0	.210	33.2	.220	31.8	0.199
3.00	20.5	.276	35.6	.209	32.2	.213	36.8	.220	33.8	.211	33.5	.204	30.1	.192
2.00	20.5	.231	29.4	.211	32.0	.203	28.7	.211	25.3	.229	28.2	.203	27.4	.203
1.00	20.5	.187	27.0	.183	35.8	.204	28.3	.202	23.4	.178	24.6	.196	26.0	.175
.50	20.5	.165	22.2	.161	21.9	.173	20.7	.158	22.3	.170	22.1	.168	21.9	.177
.25	20.5	.154	.....	.....	.....	.....	20.0	.137	.....	.....	.....	.....	.....	.....
.00	23.5	.127	23.7	.139	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

[1]Calculated.

(in which blood volume and chloride were measured 30 minutes after injection), each roach receiving 40 μ L. per gram of body weight. In five groups receiving concentrations of sodium chloride between zero and 5 N, each roach was injected with 10 μ L. per gram of body weight. In three other groups receiving 3 N, 4 N, and 5 N sodium chloride, each roach was injected with 20 μ L. per gram of body weight. In the analysis of data that follows, after certain corrections are made on the basis of the 20 μ L. actually injected, these three groups are treated as though they had been injected with 10 μ L. per gram of body weight of 6 N, 8 N, and 10 N sodium chloride, and these last values are referred to subsequently in text, table, and figures. These three groups were treated in this way to extend the sodium chloride injections beyond the limit represented by the solubility of sodium chloride in water (ca. 7 N).

To obtain an average value for the blood-volume per cent of a group of eight or ten roaches at a given time after the injection of a given concentration of sodium chloride, the arithmetic mean of the individual determinations made with the dye method was calculated. The corresponding value for chloride was the arithmetic mean of the two titrations made on the pooled blood samples from the two subgroups. These data are presented in Table I.

The normal uninjected roach is considered to have an average blood-volume per cent of 19.5, and an average blood-chloride normality of 0.142 (2). Since each roach was injected twice, with sodium chloride solution and with a saline solution of dye, it was necessary to adjust both values to allow for a slight artificial increase. Thus in Table I the blood-volume per cent immediately after injection is given as 21.5 when 20 μ L. per gram of body weight of sodium chloride solution was injected and as 20.5 when 10 μ L. was injected. A slight increase in the normal value for chloride was necessary because the injected dye was dissolved in a saline[4] having a chloride normality of 0.225. Thus, those insects previously injected with sodium chloride concentrations other than 5 N were considered to have a normal blood-chloride value raised to 0.149 N to correspond with injections of 20 μ L. per gram of body weight of dye-saline solution; and, similarly, insects previously injected with 5 N sodium chloride were considered to have a normal blood volume raised to 0.146 N to correspond with injections of 10 μ L. per gram of body weight.

The normality of chloride in the blood of an injected roach at zero time (i. e., at the instant injection is completed) may be calculated, while assuming that the injected sodium chloride solution is thoroughly mixed with the blood and that the blood has not yet been affected by any transfer of fluid between the blood and tissues. Thus, if the normality (N) and the volume (d) of the injected sodium chloride solution, and the volume (V) and the normality (N_o) of the roach's blood just prior to injection are known, the chloride normality (N_1) of the blood at zero time may be calculated from

$$N_1 = \frac{dN + V N_o}{d + V}$$

[4] 10.93 grams of NaC_2, 1.57 grams of KC1, 0.85 gram of CaC_2l, and 0.17 gram of $MgCl_2$ per liter of distilled water.

For example, the calculation of average blood normality after the injection of 10 μ L. per gram of body weight of 5 N sodium chloride into nymphs of a group having an average ratio of blood volume to body weight of 0.205 and an average blood-chloride normality of 0.146, was

$$N_1 = \frac{(5)\ (0.01)+(0.205)\ (0.146)}{0.01+0.205} = 0.372.$$

Values calculated in this way for zero time after the injection of the different concentrations of sodium chloride are given in Table I.

As the experiment proceeded, it became desirable to have approximate values for total water and total chloride in the normal uninjected roach. Total water was estimated by drying 20 weighed nymphs in an oven at 110°–115° C. for four days and then further desiccating them over calcium chloride to constant weight. There were 9 females and 11 males, whose weights ranged from 465 to 910 mg. and averaged 704 mg. The average total water content, expressed as per cent of body weight, with the standard error of the mean, was found to be 64.9±0.96. The total chloride was estimated by grinding in a mortar 3 female and 2 male nymphs together with an amount of water equal to their total weight. Each of four samples of the brei was titrated with silver nitrate (1), and the normalities were averaged. This gave an approximate value of 0.179 N.

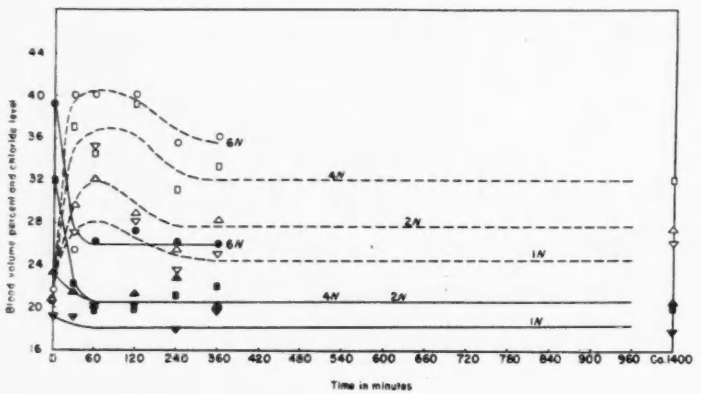

FIGURE 1. Blood-volume percent (broken lines) and chloride normality of the blood (unbroken lines) of roaches at different times after injection with different concentrations of sodium chloride. For blood-volume percent the vertical scale values are read as written; for chloride normality each value must be divided by 100. Inverted triangles, triangles, squares, and circles indicate 1 N, 2 N, 4 N, and 6 N sodium chloride, respectively.

ANALYSIS OF RESULTS

The data in Table I indicate that 30 minutes after the injection of a highly concentrated solution of sodium chloride into an average roach its blood-volume per cent was about twice that of the average normal

insect. This increase probably is due to an osmotic flow of water from the tissues into the blood. In general, the blood-volume per cent was still about twice the normal 60 and 120 minutes after injection, but

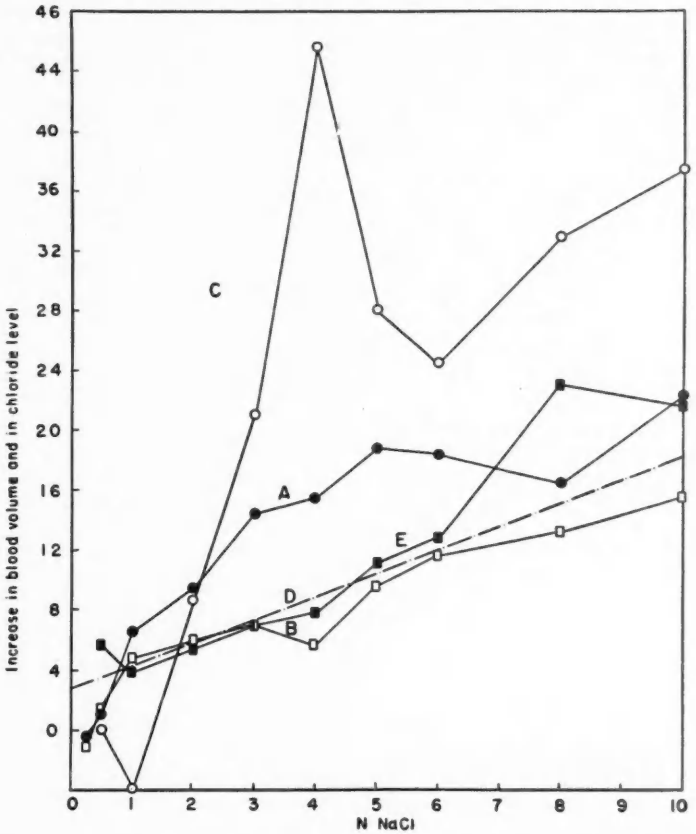

FIGURE 2. Increase in blood-volume percent and apparent blood-chloride normality above the values for the normal roach. A, Increase in blood-volume percent as determined by the dye method; B, increase in blood-chloride normality as determined by titration; C, increase in blood-volume percent as calculated from chloride increase; D, increase in blood-chloride normality as calculated from the total water content and the total chloride normality (brei) of the normal roach; E, increase in blood-chloride normality calculated on the basis of 80 percent of the blood volume as determined by the dye method. For all curves the horizontal scale is the same. For curves A and C a value on the vertical scale is the increase of blood-volume percent above the value for the normal roach; i.e., if the normal blood-volume percent were 20.5, a scale value of 16 would mean a blood-volume percent of 36.5. For curves B, D, and E a value on the vertical scale is divided by 100 and the result read as normality.

after 120 minutes it fell to a slightly lower level. Thirty minutes after injection the chloride level of the blood had fallen below the high value calculated for zero time to a level which approximately was maintained throughout the experimental period. As the concentration of injected sodium chloride was increased, blood-volume per cent attained lower and lower maximum values, but in all cases it first rose to a maximum and then fell slightly, tending to remain approximately at the lower level for about 1400 minutes. These changes are shown in figure 1.

Peters (1) summarized the findings of several authors who measured the interstitial fluids of man "by studying the concentration in the serum of injected substance to which most cells appear to be impermeable, and which are not oxidized or otherwise altered in the body." According to Peters, the results of these investigations indicate that the total volume of fluid in man is about 70 per cent of the body weight, whereas extracellular fluid (including the blood) is about 20 per cent of body weight. The blood of the roach, representing about 20 per cent of its body weight, is considered to be equivalent to the extracellular fluid in man, and the total water in the roach has been found to be 64.9 per cent of body weight. It is interesting that these values for man and for the roach are so similar.

The determination of blood volume after injection of 8 N or 10 N sodium chloride is not considered to be very reliable, for these high concentrations caused pronounced toxic effects and the circulation of the injected dye in the blood stream probably was slowed down. The data in Table I indicate, nevertheless, that the maximum blood volume increased with the concentration of injected sodium chloride up to 5 N or above, and then failed to increase much further. This is illustrated in figure 2 by curve A, which represents the increase in blood volume above the normal.

Curve A was obtained by averaging the blood volumes for 30, 60, and 120 minutes after injection, i. e., by averaging the values on the crests of curves like those shown in figure 1, except that for 10 N sodium chloride the average is for 30 and 240 minutes. Curves A, B, C, and E also were obtained by averaging values at 30, 60, and 120 minutes after injection. Comparable results were obtained by averaging the values either from 240 to about 1400 minutes or from 30 to 1400 minutes.

Curve B shows how blood chloride increases above the normal as the concentration of injected sodium chloride is increased. The curve rises rapidly at first (up to 1 N NaCl) and then more gradually, but it shows a depression localized at 4 N. Above 5 N the rate of rise of the curve becomes less. At the high concentration 8 N and 10 N sodium chloride as already mentioned, the values for blood-volume per cent may be in error because of toxic effects. But a reduced rate of blood circulation, causing an error in the blood-volume determination, would not be expected to cause an error in the chloride titration through incomplete mixing of the injected chloride with the blood, for, whereas blood volume was determined within a few minutes after the dye was injected into an insect affected by a previous injection of sodium chloride, the chloride was determined after a much longer interval (6 to 50 times as long) following the injection of the sodium chloride into the normal roach. This longer interval should have permitted a fairly complete mixing of injected chloride with the blood.

In addition to blood volumes obtained by the dye method, as discussed above, blood volumes by the pooled-blood titration method (2) were calculated for each time interval after the injection of the different concentrations of sodium chloride. Each blood volume was calculated on the basis of an average of the chloride values at 30, 60, and 120 minutes after injection. These blood volumes were plotted against the concentrations of injected sodium chloride to obtain curve C in figure 2. At concentrations up to about 2 N this curve lies near or below curve A, which represents the increase in blood-volume per cent as determined by the dye method, but soon rises to a peak at 4 N, after which it falls to lower levels but continues to remain well above curve A.

The extent to which the total water and total chloride of the normal insect are involved in the establishment of an equilibrium associated with values for chloride and blood volume after injection is not known. But, as mentioned above, the approximate volume of total water (W) in the uninjected roach was measured and an approximate value for chloride normality (T) for all tissues was obtained by titrating roach brei. By means of these approximate values and values for the normality (N) and volume (d) of sodium chloride solution injected, an approximate theoretical value for chloride normality (N_2) in an injected insect can be calculated from the expression

$$N_2 = \frac{d\,N + W\,T}{d + W}.$$

This calculation is based upon the assumption that the total water in the uninjected insect is available to dilute injected chloride.

A theoretical chloride value, assumed to hold throughout the experimental period, was calculated in this way for each concentration of sodium chloride injected. The extents to which these values exceed the blood chloride level of the normal roach were plotted against N sodium chloride injected to form curve D in figure 2.

A comparison of this theoretical curve with curve B, which represents the rise of blood chloride above the normal as found experimentally, shows that, within experimental error, the two curves lie together up to about 3 N. Except for the drop at 4 N, curve B tends to fall further below curve D as injected sodium chloride concentration increases, particularly above 5 N. This difference between curves B and D is a measure of the amount of chloride that had become nontitratable and could be due to an excretion of some of the injected sodium chloride. If this is so, the difference between the two curves at a given injected concentration (5 N or higher) would be an approximate measure of the amount of chloride excreted, expressed as normality of sodium chloride. The close proximity of the two curves in the lower concentrations indicates that all or a large part of the total water in the roach must be available for dilution of the injected sodium chloride.

The post-injection increase of blood volume, as determined by the dye method, serves as a measure of the volume of water transferred from tissues to blood as a result of the injection of sodium chloride. But the question arises as to how much chloride leaves the blood after an injection and enters the tissues. The average blood volume of the uninjected insect was found previously to be somewhat higher when

determined by the dye method than when determined by the method of chloride titration, which itself was considered to have yielded values that are somewhat too large (2). It seems probable that the dye method gave a mean value about 20 per cent higher than it should be and so the value for blood volume (V) by the dye method may be adjusted by multiplying it by 0.8. By the use of blood volume adjusted in this way and the chloride normality (N_o) of the blood of the uninjected insect, a value for blood chloride normality (N_s) after injection can be obtained from

$$N_s = \frac{d\,N + 0.8\,V\,N_o}{d + 0.8\,V},$$

where d and N have the meanings given them earlier.

By means of the average value for blood volumes at 30, 60, and 120 minutes blood-chloride normality was calculated for each concentration from the equation given above, and the increase of each value above the chloride level of normal blood was determined. These increases were plotted against the normalities of sodium chloride injected to obtain curve E in figure 2. In the lower concentrations this curve is very near curves B and D. It lies higher than curve B at 4 N and above, and higher than curve D about 6 N. If curve E were calculated on the basis of the values for blood volume given by the dye method and not corrected by the factor 0.8, it would lie near curve B at the higher and below it at the lower concentrations, an improbable situation. Unpublished data of the authors indicate that the injected sodium chloride does not begin to have a lethal effect until the concentration reaches 4 N or 5 N. If the calculations of curves D and E have been made on an admissible basis, the amount of injected chloride entering the tissues may be represented by the vertical distance of curve E above curve D, and it is of interest that the rise of curve E above curve D begins near the region of the lower lethal concentrations of injected sodium chloride.

It is not known to what extent the irregularities in the curves of figure 2 are due to experimental error. As mentioned earlier, the values for curve A at 8 N and 10 N are probably affected by a large error. These points could be considered to fall more widely about a smooth curve through the other points. If curve B is considered to be a smooth curve among all those points except the one at 4 N, which would deviate widely, then curve C (derived from B) would become correspondingly smooth but would still lie above curve A at the higher concentrations, and this would indicate a loss of chloride from the blood at these concentrations. It follows that, if a high concentration of sodium chloride were injected into a normal roach for the determination of its blood volume by the method of chloride titration, the value determined would be too high, not only because of an osmotic transfer of water from tissues to blood, but also because of a loss of chloride from the blood. Whatever may be the interpretation of the local deviations in the curves of figure 2 at 4 N and higher concentrations, the main trend of the curves is in accord with the present analysis.

Only one group of insects was injected with distilled water, and this injection resulted in negligibly small changes in blood volume and

blood chloride as determined at 30 minutes after injection. To study the effects of distilled water it would be necessary to inject much larger volumes.

SUMMARY

The quantitative injections of sufficiently high concentrations of sodium chloride into nymphs of the American cockroach, *Periplaneta americana* (L.), were followed by increases of blood volume that depended upon the concentration of sodium chloride injected and probably resulted from an osmotic transfer of aqueous solution from tissues to blood. Such an increase had occurred 30 minutes after injection. After a slight fall, the increased blood volume was maintained at an abnormally high level for 1400 minutes, beyond which no determinations were made. At 30 minutes after injection the chloride level of the blood had increased to a height dependent upon the concentration of sodium chloride injected and tended approximately to remain at the new height throughout the rest of the experimental period.

Evidence was obtained that, after an injection of a sufficiently high concentration of sodium chloride, the level of blood chloride was influenced by water entering the blood from the tissues, a large part of the total water in the insect probably becoming involved in the establishment of the new equilibrium. The data suggest that after the injection of the higher concentrations of sodium chloride some chloride passed from blood to tissues and some was rendered nontitratable, possibly as a result of excretion; when the injected concentration was not too high, apparently little or no blood chloride was lost to tissues or became nontitratable.

The total water content of the American roach nymphs was found to be approximately 64.9 per cent of body weight. The total apparent chloride normality for all tissues (brei) was approximately 0.179 N.

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A REPORT ON SOME MIOCENE DIPTERA FROM FLORISSANT, COLORADO, by Axel Leonard Melander. Amer. Mus. Novitates, no. 1407, pages 1–63, 71 figures. 1949.

In this paper, Professor Melander adds 62 species to the 167 species of Diptera previously recorded from the Florissant Miocene shales. Three of these are placed in new genera, but as the author remarks, "The significant point . . . is not that three genera have become extinct, but that 55 of the new species can be assigned to genera persisting today." This study will add considerably to our knowledge of generic evolution in the Diptera which, in most groups of that order, evidently took place before the Miocene. We still note, as in previous studies, evidence of a peculiar bombyliid fauna and a paucity of higher muscoids.

Comprehensive keys are given for the Sciaridae, Chironomidae, Bibionidae, Rhagionidae, Empididae, and the bombyliid genera *Alepidophora* and *Melanderella*.

—M. T. J.

NORTH AMERICAN BEES OF THE GENUS NOMADA, SUBGENUS CALLINOMADA

(Hymenoptera: Apoidea)

HUGO G. RODECK,
University of Colorado Museum,
Boulder, Colorado

The inquilinous bees of the genus *Nomada* are wasplike and generally brightly colored. They are relatively hairless, without abdominal hair bands, and with no pollen-collecting apparatus. They are commonly considered to be inquilines in the nests of bees, principally of the genus *Andrena*, although little of any concrete nature is known of their life-histories and they offer a fertile field for investigation.

The genus *Nomada* is large and the species variable, possibly in physiological response to different hosts. Following is a taxonomic study of a small group of species which appear to be closely interrelated, as well as sufficiently distinct as a group to bear a subgeneric name.

Genus **Callinomada** Rodeck, 1945

Ent. News, 56: 181; *N. antonita* Ckll., type.

Rather small (7–9 mm.), autumnal (August to September), sexually monomorphic species. Facial quadrangle nearly equilateral, eyes only slightly converging below. Punctures of head and thorax, especially of mesonotum, fine, distinct, dense and uniform. Dorsum of prothorax sharp-edged, produced upward at sides and depressed medially, anterior face more or less concave. Scutellum never very prominent, usually low, slightly bilobed. Hair very short and sparse, nearly absent on mesonotum and sides of propodeum, often appressed on face of males. Mandibles simple, not bidentate. Antennal scape obconic, rather slender and curved. Segment 3 of antennae from about equal to, to distinctly longer than, segment 4 in front. Tegulae long-oval, narrow, often nearly triangular. Basal vein interstitial with to definitely apicad of transverse median (Figs. 1, 2). Anterior coxae sometimes with low, rounded or conical spine rudiments but never actually spined. Apex of hind tibiae in both sexes with three to five very short, stout, acute, straight spines. Abdomen distinctly and densely punctured, hair very inconspicuous. Impunctate apical margins of abdominal terga very narrow. Seventh tergum of males broad, usually very broadly rounded, entire or minutely or very shallowly emarginate. Genitalia as in Fig. 3.

Distribution of species.—See Fig. 4.

Distinguished from *Holonomada* by smaller size, autumnal rather than vernal season, form of prothoracic dorsum, sparsity of hair, anterior coxal spine rudiments, hind tibial bristles, form of male seventh tergum, and by the male genitalia. Distinguished from *Pachynomada* by smaller size, form of prothoracic dorsum, slenderness of male scape, hind tibial bristles, form of male seventh tergum, and by the male

genitalia. All of these differ from *Micronomada* in the absence of well-developed anterior coxal spines.

Callinomada, along with *Pachynomada* and *Laminomada*, has formerly been included in *Holonomada* on the basis of the entire male seventh tergum, but examination of the male genitalia shows that *Callinomada* and *Pachynomada* are probably more closely allied to *Micronomada*, on the basis of the form of the ninth male sternum (Fig. 3).

SYNOPSIS OF SPECIES OF SUBGENUS CALLINOMADA

NOMADA

CALLINOMADA

Antonita group

antonita Cockerell.....Colorado

snowii Cresson.....Great Plains

(*omahaensis* Swenk)

mutans Cockerell.....Northwest Coast

aquilarum Cockerell.....Northern Great Plains

(*cockerelli* Graenicher)

(*dacotensis* Swenk)

Placida group

placida Cresson.....East and Midwest

verecunda Cresson.....Pacific Coast

KEY TO MALES OF CALLINOMADA

1. Light markings white..... 2
   Light markings yellow..... 5
2. Legs bright ferruginous and white, not at all blackened..... 3
   Legs black, or blackish and white..... 4
3. Small light supraclypeal mark; scape white in front; wings darkened along apical margin; complete white band on first abdominal tergum; seventh tergum more narrowly rounded.....**snowii**
   No light supraclypeal mark; scape ferruginous in front; wings hyaline; small lateral white spots on first abdominal tergum; seventh tergum broad, rounded-truncate.....**antonita**
4. Large pleural mark and peripheral fragments; scape white in front; lateral facemarks to level of antennal sockets, and separated supraclypeal mark; complete band on first abdominal tergum.....**mutans**
   No light pleural marks, scape dark in front; facemarks practically limited to malar space; first abdominal tergum all black.....**aquilarum**
5. No light markings on first abdominal tergum, bands on terga 2 and 3 interrupted; no complete dark annulus around hind tibiae.....**placida**
   First abdominal tergum usually with a complete or fragmentary yellow band; bands on terga 2 and 3 complete; a median black annulus completely around hind tibiae.....**verecunda**

KEY TO FEMALES OF CALLINOMADA

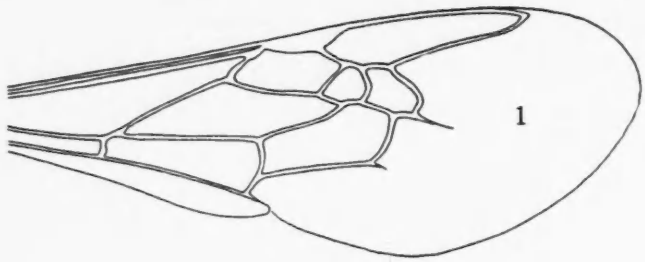
(Female of *antonita* unknown.)

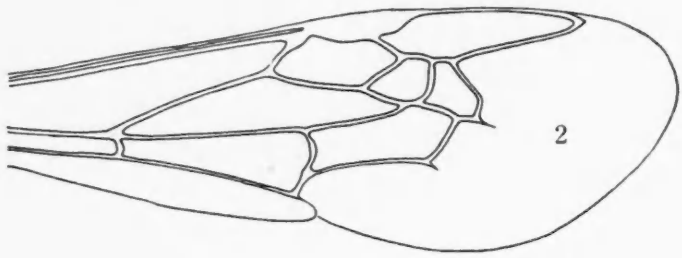
1. Light markings white..... 2
   Light markings yellow..... 4
2. Legs bright ferruginous and white, not at all blackened.....**snowii**
   Legs black or blackish, marked with white or with yellowish-ferruginous..... 3
3. Usually extensive white mesopleural marks; a white band on first abdominal tergum.....**mutans**
   No light mesopleural marks; no light band on first abdominal tergum,**aquilarum**
4. No light markings on first abdominal tergum; bands on terga 2 and 3 interrupted; no complete median black annulus around hind tibiae.....**placida**
   First abdominal tergum usually with a complete or fragmentary yellow band; bands on terga 2 and 3 complete; a median black annulus completely around hind tibiae.....**verecunda**

Nomada (Callinomada) antonita Cockerell

Nomada antonita Cockerell, Canad. Ent., 41: 35–6, 1909, male, Colorado.

Male.—Length 7–8 mm. Head and thorax black marked with snowy white as follows: mandibles except tips; labrum; postmandibular area;





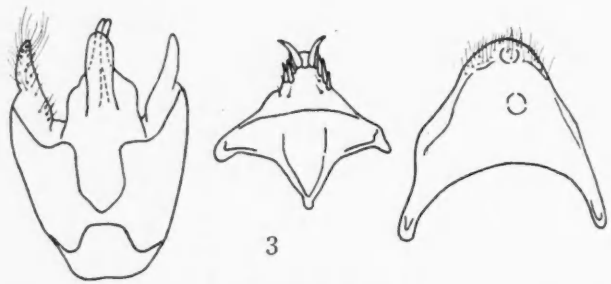


FIG. 1. Fore wing of *Nomada verecunda* (female, Oregon) showing basal vein far apicad of transverse median vein.

FIG. 2. Fore wing of *Nomada aquilarum* (male, Wisconsin) showing basal vein interstitial with transverse median vein. (Figs. 1 and 2 illustrate the approximate extremes in the relation of the basal and transverse median veins in *Callinomada*.)

FIG. 3. Genitalia (left), ninth sternum (center), and eighth sternum (right) of male of *Nomada antonita*, representing the subgenus *Callinomada*.

clypeus; lateral facemarks up the supraclypeal suture to tentorial pits, emarginate opposite the antennal sockets, thence abruptly to the orbit and continuing upward in an irregular suffused line nearly to top of eye; may be small spot at summit of eye; posterior orbits under eye and upward three-fourths of distance to top of eye; dorsum of prothorax; tubercles; a large vertical anterior pleural mark continued upward around tubercles to a point at tegulae; entire scutellum; postscutellum.

Antennal scape brown-ferruginous, strongly obconical. Flagellum ferruginous in front (segment 3 brighter), darkened behind. Segment 3 from equal to longer than 4; segment 7 broader than long. Tegulae white except for the narrow transparent rim. Wings clear, not at all darkened. Basal vein slightly apicad of transverse median.

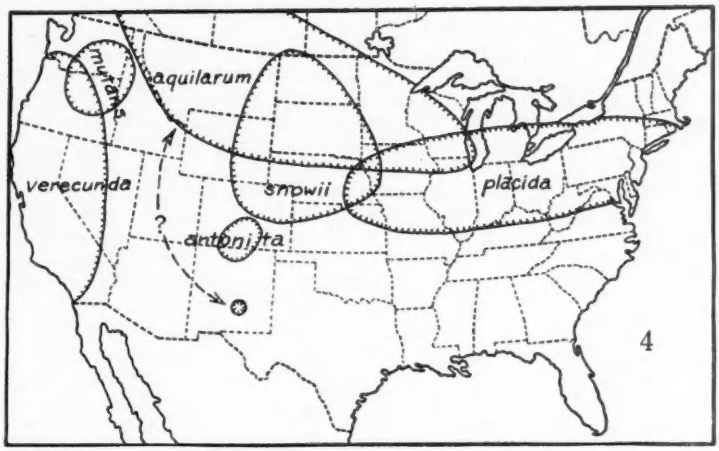


FIG. 4. Approximate known distributions of species of the genus *Nomada*, subgenus *Callinomada*.

Legs bright ferruginous with white marks as follows: on middle and hind coxae outside; apex of all femora outside and a line beneath fore and middle femora on apical half; anterior tibiae with a line down outside, second nearly all white outside, posterior with subconnected apical and basal marks outside.

Abdomen broadly oval, black, with tiny white spots far laterad on first abdominal tergum, connected by a ferruginous band. Terga 2 to 6 with complete white bands, narrowed to about one-third its lateral breadth on tergum 2. Venter of abdomen with a median subapical white spot or none on first sternum, complete broad white bands on remainder. Seventh tergum ferruginous, or white on sides, tapering, truncate-rounded at apex, and entire.

Female.—Unknown.

Specimens examined.—COLORADO: Male type (U. S. N. M. 29473), Antonito, August 5, 1900 (both right wings missing and the left front leg attached to the label); 1 male, "Colorado, 1930" (believed to be from San Luis Valley), H. G. Rodeck.

The two specimens listed are all that are known and furnish an inadequate picture of the morphology and distribution of the species.

Nomada (Callinomada) snowii Cresson

Nomada snowii Cresson, Trans. Amer. Ent. Soc., 7: 75, 1878; female, Colorado; male, Colorado.

Nomada (*Micronomada*) *snowii* Cockerell, Proc. Acad. Nat. Sci. Philadelphia, 55: 608–9, 1903; female keyed from Cresson's description.

Nomada snowii Cockerell, Colorado Agr. Exp. Sta. Bull. 94: 72, 1905; male and female included in key.

Nomada (*Holonomada*) *snowii* Swenk, Univ. Nebraska Studies, 12: 85, 1913; female, South Dakota; female, North Dakota.

Nomada (*Holonomada*) *omahaensis* Swenk, Univ. Nebraska Studies, 15: 171, 1915; males, Nebraska.

Male.—7–9 mm., rather stout. Head and thorax black with white marks as follows: more or less on base of mandibles; labrum; more or less of clypeus; lateral facemarks from malar space broadly margining clypeus to tentorial pits or beyond, thence obliquely toward eye to continue up anterior orbits narrowly to level of antennal sockets or above; line under eye and up posterior orbits from half to three-fourths distance to top of eye; dorsum of prothorax; tubercles; large anterior mesopleural spot bordering tubercle above and continuing narrowly to posterior of pleura more or less suffused and interrupted by ferruginous; often spots on sterna before middle coxae; scutellum; more or less on post-scutellum.

Antennal scape stout, obconic, ferruginous, white in front, may be darkened behind. Flagellum ferruginous, more or less darkened behind, segment 3 brighter than rest. Segment 3 somewhat longer than 4; segment 7 broader than long. Tegulae sparsely punctured and shining, white except narrow rim. Wings nearly clear or slightly and uniformly tinted, a darker area near apex. Basal vein about meeting transverse median.

Legs ferruginous marked with white, more or less darkened behind femora. White marks on legs as follows: apex of all coxae outside; line beneath anterior femora (sometimes middle also) and spot at apex of all femora above; base and apex of all tibiae outside, connected on front pair; all basitarsi outside.

Abdomen black and white. Complete (or narrowly interrupted) white bands on terga 1 to 6, enclosing small sublateral dark spots on 1, broadly narrowed medially on 1 to 4, almost entire tergum on 5 and 6. Venter of abdomen black, at most a light suffusion on sternum 1. Complete or interrupted bands on sterna 2 to 6. Seventh abdominal tergum dark fuscous, tapering, rounded-entire at apex, often with white marks on lateral pleural surfaces.

Female.—Length about 8 mm. Head and thorax black, white and ferruginous. White marks on head and thorax as follows: spot or all of base of mandible; often basal border of labrum; more or less of clypeus; malar space and lateral facemarks bordering clypeus and

lower supraclypeus, thence diagonally upward to meet anterior orbit at about level of top of antennal sockets; posterior orbits to top of eye; dorsum of prothorax; tubercles; large vertical anterior pleural spot bordering tubercles at top; entire scutellum; postscutellum. Ferruginous markings on head and thorax as follows: most of mandible; more or less of labrum and clypeus; supraclypeus; anterior orbits from facemarks over top of eye to postorbital white; all of mesopleurae and sterna except upper margins, more or less of sides and rear of propodeum, sometimes with suffused spots on triangular enclosure.

Antennal scape short, stout, curved, ferruginous. Flagellum ferruginous in front, segment 3 brighter; flagellum darkened behind except segment 3. Segment 3 hardly longer than 4; segment 7 about as broad as long. Tegulae white except for narrow ferruginous rim. Wings rather uniformly darkened; a clearer area beyond the third cubital cell. Basal vein slightly apicad of transverse median.

Legs bright ferruginous marked with white as follows: on all coxae outside; may be a line beneath apical half of fore and middle femora; on outside apex of all femora; all tibiae at apex and base outside.

Abdomen broad oval, ferruginous at base, black and white beyond. White abdominal marks as follows: small, lateral subapical spots on the ferruginous first tergum, at times with small black spots just anterior to them; second tergum with a broad band broadly narrowed to about one-third its lateral breadth by an anterior invasion of black; third tergum similar but narrower laterally; fourth and fifth terga with white bands nearly covering the segment. Venter of abdomen ferruginous and white. White band on second sternum sublaterally emarginate from the front and perhaps narrowly interrupted medially; similar on third but continuous; a straight complete band on fourth; the apical margin of fifth sternum.

Specimens examined.—COLORADO: Lectotype female (Phila. Acad. Nat. Sci. No. 2597), "Col. Snow"; female, Boulder, Aug. 18, 1929, W. W. Greulich. NEBRASKA: Male type of ***omahaensis*** (University of Nebraska), Omaha, Aug. 29, 1914, on *Solidago canadensis*, L. T. Williams. NORTH DAKOTA: Male, Williston, Aug. 9, 1915, on *Grindelia squarrosa*, O. A. Stevens.

I have not examined the male described with the type female by Cresson, which presumably is in the Philadelphia Academy collection, from "Colorado, Morrison." Its markings are described as yellow. A paratype of ***omahaensis*** which I examined at the University of Nebraska has the legs much darkened behind and a nearly black "annulus" around the hind tibiae much like that of ***mutans***.

Nomada (Callinomada) mutans Cockerell

Nomada (Holonomada) mutans Cockerell, Psyche, 17: 91–2, 98, 1910, females, Washington.

Male (Allotype by present designation).—Length about 7 mm. Head and thorax black with white marks as follows: mandibles except tips; labrum; clypeus, separated from white of supraclypeus and lateral facemarks down to tentorial pits; supraclypeal spot; lateral facemarks, including malar space, from tentorial pits diagonally toward orbit well below level of antennal sockets, thence a narrow line upward along orbit

to level of antennal sockets; postmandibular area and fragmentary line half way up posterior orbits; dorsum of prothorax; tubercles; divided antero-posterior pleural mark and a curved mark below and behind tubercles; scutellum; sternal spots antero-mediad of middle and hind coxae.

Antennal scape obconic, curved, white in front, dark ferruginous behind. Antennal segment 3 yellowish-ferruginous in front, rest of flagellum darker ferruginous in front, still more darkened behind. Segment 3 rather slender, about one-fourth longer than 4; segment 7 broader than long. Tegulae white except narrow rim and central mark. Wings only slightly darkened on apical margin. Basal vein slightly apicad of transverse median vein.

Legs blackish, anterior pair ferruginous in front. Creamy white marks on legs as follows: all coxae outside; apices of all femora on top, beneath anterior and middle pair, hind pair all around; whole outside of anterior tibiae; apex and base connected by a line outside of middle tibiae; apex and base with blackish zone between on hind tibiae; all basitarsi.

Abdomen robust, black and white. Terga 2 to 6 punctured to the edge. White marks on abdomen as follows: complete bands on terga 1 to 6, notched medially in front on tergum 1 and enclosing small dark spots sublaterally; on tergum 2 gradually narrowed nearly one-half medially; narrowed medially on 3; subuniform on 4 and 5 but slightly emarginate sublaterally from the front; tergum 6 nearly all white. Venter of abdomen very dark blackish-ferruginous, distinctly punctured. White bands on sterna 2 to 5, enclosing sublateral dark spots on 2 and 3, emarginate sublaterally from the front on 4 and 5. Seventh tergum black, somewhat broad, rounded-entire at apex.

Allotype, male, Yakima, WASHINGTON, no other data, from R. D. Shenefelt, State College of Washington, Pullman.

Female.—6½–8 mm. Head and thorax black with white marks as follows: mandibles except tips; labrum more or less; clypeus except upper margin down to tentorial pits; lateral facemarks irregularly upward around antennae from tentorial pits to end in a narrow blunt point, distinctly separated from eye, about three-fourths or more up anterior orbit; under eye and up posterior orbits three-fourths or more to top of eye; dorsum of prothorax; tubercles; low anterior and posterior pleural spots, often connected, and a lunate mark below and behind tubercles; more or less of scutellum; postscutellum more or less; spots antero-mediad of middle and hind coxae. Labrum with a reddish median denticle apically.

Antennal scape stout, more or less yellowish in front, ferruginous or dark behind. Flagellum ferruginous, somewhat brighter in front. Segment 3 of antennae about a third longer than 4; segment 7 about as broad as long. Tegulae white except rim. Wings uniformly very slightly darkened, a little more so at apex. Basal vein distinctly apicad of transverse median.

Legs dark ferruginous or blackish, anterior pair lighter in front, marked with white as follows: spots on all coxae; lower edge of front and middle femora near apex and extreme apex of all femora above; base and apex of all tibiae outside, often connected by a line on anterior pair; line on middle and hind basitarsi.

Abdomen black with white complete bands on all terga, enclosing small sublateral dark spots on tergum 1, narrowed to one-half lateral breadth on tergum 2, narrowed medially on 3, sublaterally emarginate from the front on 4, the fifth often nearly all white but with broad sublateral emarginations from the front. Venter of abdomen dark ferruginous with white bands on sterna 2 to 5, enclosing sublateral dark spots on 2 and 3, emarginate sublaterally from the front on 3, 4, and 5, or sometimes all sterna except first with separated lateral marks, variously emarginated.

Variation.—Examination of Cockerell's female type shows that the basal vein is actually apicad of the transverse median vein, rather than basad as given in his description, which is in accord with the usual condition in *Callinomada*. Cockerell's *var. a* with black postscutellum, and emarginations rather than enclosed spots on the first abdominal tergum, and his *var. b*, which is very small, with restricted facemarks, two-spotted scutellum, black postscutellum, and emarginate bands on abdominal terga 4 and 5, are both well within the range of variation to be expected. The smaller specimens (resulting from small host?) tend to show greater restriction of the white markings and less blackness of the dark areas, tending toward ferruginous.

Specimens examined.—OREGON: Female, Antelope Mt., Harney Co., 6500 feet elevation, Aug. 14, 1931, D. K. Frewing. WASHINGTON: Female type (U. S. N. M. 13192), 2 female paratypes (vars. a and b), Pullman, Aug. 9, 1908, W. M. Mann; male allotype, Yakima.

Nomada (Callinomada) aquilarum Cockerell

Nomada aquilarum Cockerell, Ann. Mag. Nat. Hist., (7) 12: 208–9, 1903, male, New Mexico.
Nomada aquilarum Cockerell, Colorado Agr. Exp. Sta. Bull. 94: 74, 1905, in key.
Nomada cockerelli Graenicher, Bull. Publ. Mus. City Milwaukee, 1 (art. 3): 240, 1911, male, Wisconsin.
Nomada (*Holonomada*) *aquilarum* Swenk, Univ. Nebraska Studies, 12: 86–8, 1913; male, North Dakota; female, North Dakota.
Nomada (*Holonomada*) *dacotensis* Swenk, Univ. Nebraska Studies, 12: 88–9, 1913; females, North Dakota.

Male.—7–8 mm. Head and thorax black with white marks as follows: mandibles except tips; labrum; lower portion of clypeus; malar space and sometimes narrow lateral facemarks usually not extending as high as antennal sockets; tubercles; sometimes dorsum of prothorax; spots on scutellar apices or coalesced. Pleurae and propodeum extremely dark ferruginous, or black. Dark median denticle near apex of clypeus.

Antennal scape conical-curved, ferruginous, sometimes yellowish in front. Flagellum ferruginous, hardly darkened behind. Segment 3 slightly longer than 4 in front; segment 7 broader than long. Tegulae partially impunctate, ferruginous except usually an apical yellow spot and narrow ferruginous rim. Wings slightly darkened, nearly uniform. Basal vein interstitial or slightly basad of transverse median vein (Fig. 2).

Legs dark ferruginous or blackish (except anterior which are yellowish in front) marked with white as follows: on base and apex all tibiae

outside, sub-connected on first pair, sometimes on second; usually apex of all femora on top.

Abdomen fusiform, dark ferruginous or black, marked with white. Usually no white on first abdominal tergum which is all deep mahogany; on terga 2, 3, and 4 are more or less widely separated cuneiform marks pointed mediad, rarely joined medially; a subinterrupted narrow band on 5; a complete band on tergum 6. Venter of abdomen dark ferruginous usually with arcuate sublateral white marks on sterna 2 to 4, often absent on 2, joined medially on sternum 5. Seventh tergum black, broad, rounded-truncate and entire at apex.

Female.—7–9 mm. Head and thorax black with ivory white marks as follows: very restricted lower lateral facemarks or none; a narrow line or none on dorsum of prothorax; tubercles; more or less of scutellum.

Antennal scape moderately slender, slightly curved, dark ferruginous with bright spot at base in front. Flagellum ferruginous in front, darkened behind, segment 3 often bright in front. Segment 3 of antennae hardly as long as 4 in front; segment 7 about as broad as long. Tegulae dark mahogany with small ivory spot near margin, punctate basally, impunctate apically. Wings uniformly slightly darkened with a clearer area near apex. Basal vein nearly interstitial to slightly basad of transverse median vein (Fig. 2).

Legs dark mahogany except anterior pair bright in front. White spots at base and apex of hind tibiae outside, or an irregular line connecting the two.

Abdomen rather flattened, fusiform, black and ivory white, so finely punctured as to leave the surface rather shiny. No ivory marks on tergum 1; on tergum 2 separated cuneate marks pointed mesad; on 3 similar but narrower marks; on 4 an irregular line, entire or interrupted medially, and emarginate sublaterally from the front; on 5 a subapical band emarginate sublaterally from the front. Venter of abdomen blackish, finely punctured. Lateral arcuate subapical lines on abdominal sterna 3 and 4, sometimes obscure on 3, occasionally fragments on 2. White marks on abdominal venter sometimes more extensive.

Specimens examined.—ALBERTA: Female, Lethbridge, Aug. 21, 1923, H. E. Gray; male, Beaverlodge, July 19, 1931, O. Peck (locality about 55° N. Lat!). NEW MEXICO: Male type (U. S. N. M. 13183), White Mts., South Fork Eagle Creek, about 8000 feet, Aug. 18, on *Erigeron macranthus*, C. H. T. Townsend. NORTH DAKOTA: Female allotype, Fargo, July 31, 1910, on *Lactuca pulchella*, O. A. Stevens; female type of *dacotensis* (Univ. Nebr. 2803), Fargo, Aug. 17, 1911, on *Grindelia squarrosa*, O. A. Stevens; female paratype of *dacotensis*, Fargo, Aug. 14, 1911, on *Melilotus alba*, O. A. Stevens; Female, Fargo, Aug. 25, 1917, O. A. Stevens; male, Granville, Aug. 7, 1915, on *Grindelia squarrosa*, O. A. Stevens. WISCONSIN: Male of *cockerelli*, Milwaukee, July (?) 15, 1908, S. Graenicher; male, Worden Township, Clark Co., July 27, 1919, on goldenrod, F. J. W. Schmidt. WYOMING: Male, Yellowstone Nat. Park, July 23, 1930, F. E. Lutz.

The specimen of *aquilarum* from Worden Township, Clark County, Wisconsin, 27 July 1919, is very like Cockerell's New Mexico type, except for larger size. It has fairly large light spots on the scutellar

lobes, but the type of *aquilarum*, contradicting the original description, has tiny ivory spots on the scutellar lobes. I have tried to find some basis for the separation of Cockerell's New Mexico specimen and those from Wisconsin, North Dakota, Wyoming and Alberta, but am unable to do so. They appear to be the same species, and it may be that subsequent collections will ultimately connect the two areas.

Nomada (Callinomada) placida Cresson

Nomada placida Cresson, Proc. Ent. Soc. Philadelphia, 2: 291–2, 1863, female, male, Pennsylvania.
Holonomada placida Robertson, Canad. Ent., 35: 177, 1903, female, male.
Nomada (Holonomada) placida Swenk, Univ. Nebraska Studies, 12: 83 (key pp. 77–8), 1913.
Nomada (Holonomada) placida "Robertson" Viereck, Connecticut State Geol. and Nat. Hist. Surv. Bull. 22: 724–727, 1916, male, female, keys.

Male.—7–8 mm. Head and thorax black marked with yellow as follows: mandibles except tips; labrum; clypeus except upper margin down to tentorial pits; malar space, usually also lateral facemarks not extending higher than the level of antennal sockets; sometimes a postorbital line not more than half-way up posterior orbits; more or less of dorsum of prothorax; tubercles; small low anterior mesopleural spot or none; scutellum; more or less of postscutellum.

Antennal scape slender, curved-obconic, ferruginous-yellowish in front, brighter at base, blackened behind. Flagellum yellowish or ferruginous in front, blackened behind. Antennal segment 3 somewhat longer than 4 in front; segment 7 about as broad as long. Tegulae sparsely punctured, yellowish-ferruginous. Fore wing uniformly slightly darkened, or more so near apical margin. Basal vein nearly interstitial or slightly apicad of transverse median vein.

Legs rather pale ferruginous, marked with yellow as follows: middle and hind coxae on outer edge; all femora at apex above and front and middle pair beneath near apex; whole outside of all tibiae but invaded medially on hind pair; all tarsi.

Abdomen dark ferruginous to black, marked with yellow. First abdominal tergum all dark; second tergum with large lateral cuneate marks which may join medially; similar on tergum 3 but narrower; on 4 a narrow subapical band, at times interrupted medially and shallowly emarginate sublaterally from the front; 5 and 6 usually with complete narrow bands. Venter of abdomen black, densely and distinctly punctured. Usually yellow sublateral spots on sternum 2 and complete bands or arcuate lateral marks on sterna 3 to 5. Seventh tergum rather narrow, black, rounded-truncate and usually entire at apex, but sometimes shallowly or minutely notched.

Female.—7–8 mm. Head and thorax black with yellow marks as follows: mandibles except tips; labrum; clypeus except upper margin; lateral facemarks from clypeus, widely emarginate around antennal sockets, concavely to a narrow point, suffused with ferruginous, near top of eye; sometimes a postorbital line; dorsum of prothorax; tubercles; small anterior mesopleural mark; scutellum; postscutellum. Supraclypeal mark ferruginous; sides of propodeum dark ferruginous.

Antennal scape slender, curved, ferruginous, bright at base in front, darkened behind. Flagellum bright ferruginous at base and darker

apically. Segment 3 about as long as 4; segment 7 slightly longer than broad. Tegulae punctured, ferruginous. Wings rather uniformly slightly darkened. Basal vein interstitial with transverse median vein.

Legs ferruginous, not much blackened behind. Yellow marks on hind coxae and a complete yellow line down outside of all tibiae, expanded at apex and base of hind pair.

Abdomen very dark ferruginous with yellow markings as follows: at most a suggestion on tergum 1; large cuneate lateral marks, approximated medially on tergum 2; on 3 similar but more wide separated; on 4 and 5 complete bands emarginate sublaterally from the front. Venter of abdomen ferruginous, distinctly and densely punctured, with fragments of lateral marks on sternum 3; complete band on 4.

Specimens examined.—DISTRICT OF COLUMBIA: Male, Washington, W. H. Ashmead. ILLINOIS: Male, Carlinville, Sept. 21, 1903, on *Aster ericoides villosus*, Charles Robertson. INDIANA: Female, Lafayette, Sept. 1930, George G. Ainslie. NEBRASKA: Female, Lincoln, September. NEW JERSEY: Female, Montclair, Sept. 4, 1931, M. A. Cazier. NEW YORK: Male, Fort Montgomery, Sept. 9, 1917, F. M. Schott. PENNSYLVANIA: Lectotype female (A. N. S. Phila. 2600), "Penn."; male, Carlisle Junction, Aug. 28, 1909, W. S. Fisher; female, Glenside, Sept. 15, 1908, G. M. Greene. VIRGINIA: Male, Minor's Hill, Falls Church, Sept. 13, 1912, C. T. Greene; male, E. Falls Church, Sept. 19, 1920, S. A. Rohwer.

Nomada (**Callinomada**) **verecunda** Cresson

Nomada verecunda Cresson, Trans. Amer. Ent. Soc., 7: 203, 1879, female, male, Nevada.

Nomada verecunda Cockerell, Proc. Acad. Nat. Sci. Philadelphia, 55: 593, 1903, male in key only.

Male.—8–9 mm. Head and thorax black with yellow marks as follows: mandibles except tips; postmandibular area; labrum; clypeus except upper margin above tentorial pits; sometimes a separated supraclypeal mark; malar space and lateral facemarks widely emarginate around antennal sockets to anterior orbits, thence narrowly up orbits in a ferruginous-suffused line, often nearly to top of eye; sometimes a small post-mandibular area; dorsum of prothorax; tubercles; large irregular pleural mark usually antero-posteriorly bilobed or divided and anterior lobe usually with an upward extension below and behind tubercle; spots inside middle coxae; scutellum; more or less on postscutellum.

Antennal scape obconic, curved, with irregular yellow line in front, darker behind. Flagellum ferruginous in front, dusky behind. Antennal segment 3 slightly longer than 4; segment 7 considerably broader than long. Tegulae nearly triangular, yellow except narrow margin. Fore wing slightly darkened apically. Basal vein far apicad of transverse median (Fig. 1).

Legs black or dark ferruginous marked with yellow as follows: all coxae; apical half or more of all femora in front and apical third of hind femora behind, others as in front; fore and middle tibiae with a median darkened spot behind, hind tibiae with a complete median dark zone ("annulus"), yellow basally and apically; all tarsi yellow.

Abdomen dark ferruginous marked with yellow. Complete subuniform yellow bands on abdominal terga 1 to 6. Venter with complete bands on sterna 2 to 6, often an irregular median mark on sternum 1. Seventh tergum often yellow at base, ferruginous apically, rather broad, tapering, often minutely but distinctly notched at apex which is rounded.

Variation.—A male from Nevada, probably one of Cresson's specimens, in the Cockerell collection, is small and very slender, has no yellow in front of scape, no mesopleural mark, and no yellow on postscutellum or anterior coxae. It possibly represents the minimum development of yellow coloration in males of the species. The mesopleural yellow is often confined to a low anterior mark, or none at all, the scutellar yellow is often restricted to two tiny, apical dots, there may be no yellow on prothoracic dorsum and the yellow of first abdominal sternum may be fragmentary or reduced to lateral spots.

It is perhaps significant that these restrictions in light coloration are exhibited by the small, slender, fragile specimens while the larger, more robust specimens, like Cresson's lectotype male, show the greatest color development. I suspect that these may be biological races, inquilinizing different host species, with consequent differences in amount, and perhaps kind of food. It is such conjectures as this which complicate (and add zest to) the taxonomy of *Nomada* and which suggest that the definitive taxonomy of the genus will depend on the accumulation of life-history data, including host relationships.

Cresson's lectotype male (A. N. S. Phila. 2565) is obviously not the specimen (or one of the specimens) from which he drew up his original description of the male of *verecunda*. It appears from the description that he had before him a small (0.30–0.35 inch) specimen with restricted yellow markings, as indicated by such phrases as "face-not so broadly yellow at the sides" (as in the female), "the yellow spots on pleura reduced or entirely wanting." The lectotype is a large specimen (9 mm.) with lateral facemarks extensive, and with a large, irregular, antero-posteriorly bilobed mesopleural yellow patch, the anterior lobe of which extends upward to border the tubercle beneath and behind.

Such large robust specimens with extensive yellow markings seem to have the dorsum of the prothorax less sharply edged than the smaller specimens, although they show the laterally upward-produced dorsum and concave anterior face. Large specimens may also tend to have the basal vein more nearly meeting the transverse median, although the lectotype has it far apicad of the transverse median (Fig. 1).

Female.—7 mm. Head and thorax black with yellow marks as follows: mandibles except tips; labrum; clypeus except upper margin above tentorial pits; sometimes a supraclypeal spot; malar space and lateral facemarks, emarginate around antennal sockets, nearly to top of eye; postmandibular area and up posterior orbits nearly to top of eye; dorsum of prothorax; tubercles; low anterior and posterior mesopleural spots sometimes joined into one large patch, and with an upward anterior extension to border the tubercle beneath and behind; spot anteromediad of middle coxae; scutellum; postscutellum.

Antennal scape slender, curved, suffused yellowish in front, darkened behind. Flagellum ferruginous in front, antennal segment 3 brighter,

slightly darkened behind. Antennal segment 3 slightly longer than 4 in front; segment 7 about as broad as long. Tegulae nearly triangular, sparsely punctured, yellow except narrow rim. Wings uniformly very slightly darkened. Basal vein from interstitial to far apicad of transverse median vein (Fig. 1).

Legs dark ferruginous marked with yellow as follows: spot on outer edge of all coxae; apices of all femora, the entire front and a line down lower edge of anterior pair; all of anterior tibiae, but a median suffused dark zone nearly around middle pair and a complete nearly black zone around hind pair separating apical and basal yellow; all tarsi yellow more or less.

Abdomen dark ferruginous with yellow marks as follows: complete bands on terga 1 to 5; subuniform and enclosing small sublateral dark spots on 1; on 2 narrowed medially to half the lateral breadth; on 3 similar but narrower; on 4 subuniform with sublateral emarginations from the front; similar on 5. Venter ferruginous with complete or incomplete irregular bands on sterna 2 to 5, variously enclosing sublateral dark spots, or emarginate from the rear, or interrupted medially or sublaterally.

Variation.—At first glance at the females it appears that it might be possible to separate two forms, somewhat as follows:

Large mesopleural patch with extension toward tubercle; basal vein nearly interstitial; dorsum prothorax more rounded; 6–7 spines at apex hind tibiae; size larger, more robust. . . . . **Form 1**

Small low mesopleural spots, basal vein definitely apicad of transverse median; dorsum prothorax sharper-edged; 4–5 spines at apex hind tibiae; size smaller, more slender. . . . . **Form 2**

but these distinctions are apparently not valid, as there are intermediates, as well as representatives of both forms with the same collection data.

Specimens examined.—CALIFORNIA: Male, San Pedro, Oct. 25, 1909, G. R. Pilate; female, near Lake Eleanor, Yosemite Nat. Park, July 29, 1930, E. C. Zimmerman. NEVADA: Male lectotype (A. N. S. Phila. 2565), "Nevada"; 2 males, "Nevada" (in Cockerell coll., probably Cresson specimens). OREGON: 4 males, female, Pole Bridge Meadow, Crater Lake Nat. Park, 5900 feet, Aug. 11, 1935, George Ferguson; 10 females, Mount Hood, 3000–6000 feet, Aug. 5, 1925, C. L. Fox; female, "W. Lava," Three Sisters, Aug. 15, 1926, H. A. Scullen; female, Sparks Lake, Deschutes Nat. Forest, 4800 feet, Aug. 21, 1937, Bolinger-Jewett; female, Elk Lake, Deschutes Nat. Forest, 4600 feet, Aug. 21, 1937, Bolinger-Jewett.

EMBRYOLOGY OF THE MILKWEED BUG, ONCOPELTUS FASCIATUS (HEMIPTERA), by F. H. BUTT. Cornell Univ. Agr. Exp. Station Memoir 283, 43 pages, 58 figures, 1949.

The outstanding interest of this study lies in the fact that it is only the second complete study of the embryology of a heteropteron. The work presents a good appearance, with clear illustrations, and should be of great value to students of insect embryology.—M. T. J.

A NEW SPECIES OF CTENICERA FROM THE MID-WEST

(Coleoptera, Elateridae)[1]

EDWARD C. BECKER,[2]
University of Illinois, Urbana, Illinois

In material of Elateridae from Arkansas, Kentucky, and Tennessee, there were several specimens of an interesting new species of *Ctenicera* which superficially resembles *trivittata* (Lec.) to a remarkable degree. Detailed study has brought to light several structural differences, especially in the prothorax, which separate the two forms. I am greatly indebted to Dr. Merton C. Lane for first diagnosing this species as new, and for continued assistance in this investigation.

Ctenicera lanei n. sp.

Male.—Length 15 mm., width 5 mm. Robust, very convex; head and antennae black; pronotum black with two broad sublateral stripes very dark reddish-brown, each stripe equal to one quarter of the width of the pronotum and not attaining the hind angles or the anterior angles; elytra yellow; scutellum, sutural stripe, and each humeral stripe, black; legs and underside dark brown; surface above somewhat shiny, moderately covered with short yellowish-gray pubescence which is very sparse on the elytra.

Head one half as wide as the pronotum; coarsely, closely punctured, front very little concave; antennae reaching two segments beyond the apices of the hind angles, second segment globular, third cylindrical, one and one half times the length of the second, segments four to ten serrate, each distinctly longer than wide.

Pronotum slightly wider than long, including the posterior angles; sides nearly parallel on the posterior half, thence rounded to the front angles; disc strongly convex; posterior angles divergent, each with a strong, but not sharply defined, carina parallel to the side; punctures coarse, separated by their own diameters on the disc and approximate at the sides; narrow, median, nearly punctureless, longitudinal area extending the entire length of the pronotum.

Elytra hardly twice as long as wide, widest at the apical third; each elytron with a black sutural stripe two intervals wide at base tapering to one interval wide at one half the length of the elytron; sixth and seventh intervals and adjoining parts of the fifth and eighth intervals with an irregular black humeral stripe extending from base to apex; sides of elytra evenly rounded, tapering to a blunt apex; striae impressed, punctures sparse and moderate; intervals punctulate, transversely wrinkled, and convex; supplementary stria present on the basal four

[1]This paper is a joint contribution from the Department of Entomology, University of Illinois, and the Illinois Natural History Survey, Urbana, Ill.

[2]Laboratory Assistant, Illinois Natural History Survey, during summer, 1948.

fifths of the ninth interval of each elytron where it then converges with the tenth stria.

Genitalia as in Fig. 5.

Female.—Length 12 mm., width 4.5 mm. Antennae extending only two thirds the length of the pronotum; the form and proportions of the segments are similar to those of the male except segments nine and ten are about as wide as long. The narrow median longitudinal area of the pronotum is punctured on the middle third, and free of punctures on the basal and apical thirds. The elytra are orange and the humeral stripes are more irregular. The supplementary stria extends on the basal two thirds of the ninth interval. Genitalia as in Fig. 6.

Holotype.—Male, Reelfoot Lake, Tennessee, March 29, 1948, L. J. Stannard; collection of the Illinois Natural History Survey.

Allotype.—Female, Washington County, Arkansas, January 15, 1938, University Farm, in soil in edge of small grain field, M. W. Sanderson; same collection as the holotype.

Paratypes.—One male, same data as the holotype; two males, Edmonton County, Kentucky, July 20, 1919, G. W. Bock.

The paratypes vary from 11.5 mm. long and 3.5 mm. wide to 15 mm. long and 5 mm. wide. With the exception of a slight difference in the supplementary elytral striae and the size, the paratype with the same data as the holotype is identical with it. On two of the paratypes the supplementary striae are very distinct and stop abruptly about the middle of the elytra. The two paratypes from Kentucky have orange elytra, and the humeral stripe is similar to that of the allotype. The antennae extend only one segment beyond the hind angles of the prothorax and the general color of the stripes is a light brown on one specimen.

This species could be easily confused with *trivittata* as the elytral and thoracic markings are almost identical. *C. lanei* is more robust, being three times as long as wide, whereas *trivittata* is three and one half times as long as wide. The most striking difference between the species is seen from the lateral aspect; the pronotum is much more convex in *lanei* and the prosternum is nearly straight, Fig. 4; in *trivittata* the pronotum is less convex and the prosternum is sinuate, Fig. 3. Also from the side the elytron of *trivittata* slopes gradually from the base to the apex, and in the new species it is nearly parallel to the abdomen for the basal two thirds and then slopes rather suddenly to the apex. From the dorsal aspect the elytra of *trivittata* narrow gradually from the base to the apex, and with *lanei* the elytra widen slightly from the base to the apical third and then narrow to the apex. The antennal segments four to ten are about as wide as long in *lanei*, Fig. 1, but are one and one half times as long as wide in *trivittata*, Fig. 2. In *trivittata* the elytron has no supplementary stria; in *lanei* there is a supplementary stria between the ninth and tenth striae. The differences in the male genitalia are slight, as shown in Figs. 5 and 7. In *lanei* the outside margin of each lateral lobe is straight or nearly so; the basal projections of the median lobe definitely converge, and the bases of the lateral lobes on the ventral side extend considerably below the base of the elongate chitinized structure lying on the median lobe; in *trivittata* the outer margin of the

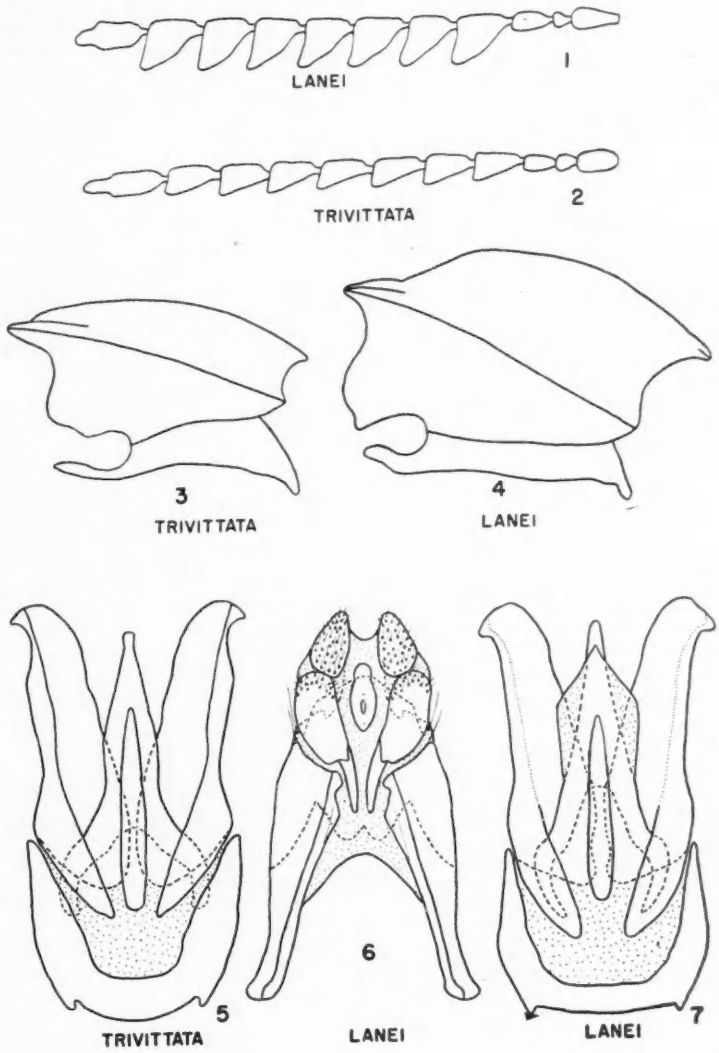


FIG. 1. *Ctenicera lanei*, male antenna. FIG. 2. *C. trivittata*, male antenna. FIG. 3. *C. trivittata*, prothorax, lateral aspect. FIG. 4. *C. lanei*, prothorax, lateral aspect. FIG. 5. *C. trivittata*, male genitalia, ventral aspect. FIG. 6. *C. lanei*, female genitalia, ventral aspect. FIG. 7. *C. lanei*, male genitalia, ventral aspect.

lateral lobe is curved, the ends of the base of the median lobe are not, or at most very little, converging, and the bases of the lateral lobes on the ventral side extend but very little below the base of the median structure. The female genitalia of *Ctenicera* have never been figured; illustrations of these structures are given for completeness of description rather than for comparative use.

AN IMPORTANT NEW ENTOMOLOGICAL PERIODICAL FROM JAPAN.—In this journal (*Annals Ent. Soc. Amer.* 33: 510–512) a summary of entomological periodicals in Japan was presented, with remarks on cessation dates due to the recent war and on other details. Previously (*Ent. News* 57: 19–20) a new post-war entomological periodical had been announced.

Through the kindness of Professors Toichi Uchida and Chihisa Watanabe of the Entomological Institute, Hokkaido Imperial University, Sapporo, Japan, I have received copies of an important new Japanese entomological journal, MATSUMUSHI. It is the Japanese language companion to INSECTA MATSUMURANA, which contains papers only in European languages. The latter journal has not yet resumed publication because of unavailability of materials. Of the four editors of MATSUMUSHI, Drs. Watanabe and Hirosi Takahasi are members of the Entomological Society of America, and Dr. Uchida is a former member. Mr. S. Hukusima is the other editor.

Volume I of MATSUMUSHI includes two numbers, dated September and December, 1946. According to the announcement in the first issue all succeeding volumes will contain four numbers. Volume II, number 1, is dated June, 1947.

Though papers in MATSUMUSHI are in Japanese, three of the four taxonomic papers in the first three issues have thorough English resumés. The remaining papers have only enough scientific names and names of entomologists to be very tantalizing. The figures, with English wording, further arouse the reader's interest but not satisfaction. The subject matter is obviously of considerable importance. Dr. Watanabe has furnished me with brief summaries of much of the content of the three issues.

Professor Emeritus Shonen Matsumura, father of Japanese entomology, in the foreword of the first issue, calls for the post-war revival of entomology in Japan and a plea for application of knowledge to aid in solving the food problem. Dr. K. Yasumatsu has papers on tree-hole rubbish fauna, Mutillidae from East China, and a new chalcid from Japan (*Dromochalcidia nigra*). Dr. C. Watanabe has papers on a revision of the world Paxylommatidae, the Japanese *Leucospis*, and the necessity for a national museum in Japan. Mr. K. Tsuneki has a paper on the nomenclature of the Japanese Chrysididae and several notes on habits of Crabronidae. T. Shirozu has a large paper on the zoogeography of Japanese butterflies. There are several papers on various aspects of economic pest insects by Hukusima, Kuwayama, Nishijima, Kato, Utida, Fukuya, Nagasawa, Moritsu, Ozawa, and Takeya. Dr. H. Takahasi gives a list of mosquitoes of Hokkaido and a translation of the reviewer's paper on *Uranotaenia* feeding (*Ent. News* 56: 32–37, 64–68). A study of diurnal activity of mosquitoes is by five authors. There are book notices of Tsuneki's "Hunting Wasps" and Watanabe's book on Japanese parasitic Hymenoptera. T. Shimizu has a notice on the new plant quarantine. Of particular interest are reports from noted Japanese entomologists who were in Japanese invaded territory or elsewhere when the war ended. Their whereabouts and safety had been uncertain at that time. MATSUMUSHI has reports from Dr. R. Takahashi back from Malaya, Dr. K. Iwata returned from Hainan Island, A. Kawada from Java, R. Yoshii from Europe, and Dr. Y. Miwa and M. Chujo from Formosa. The famous professors from Taihoku Imperial University, Shiraki and Issiki, remained in Formosa with their great collections and library.

Professor Watanabe has informed me that he is very desirous of establishing permanent exchanges of MATSUMUSHI for all other entomological periodicals. Correspondence should be addressed to Editors of Matsumushi, Entomological Institute, Hokkaido University, Sapporo, Japan.—CHARLES L. REMINGTON.

A BIOLOGICALLY ANNOTATED LIST OF THE BUPRESTIDAE OF THE LOWER RIO GRANDE VALLEY, TEXAS[1]

GEORGE B. VOGT,
University of Maryland,
College Park, Maryland

During the period between January 1, 1946 and October 6, 1947, the writer collected insects regularly on weekends over much of the area generally known as the Lower Rio Grande Valley, Texas. The Buprestidae are well represented in the resulting collection and a list of the 63 species taken are here given with biological notes.

For verification of many of the identifications of the Buprestidae listed here, for much sound advice and no small measure of encouragement and general assistance, the writer is gratefully indebted to Mr. W. S. Fisher of the U. S. National Museum. Dr. J. N. Knull of the Ohio State University, has kindly read the manuscript and compared a number of specimens with types in his collection. For determinations on most of the plants referred to in this paper, the writer expresses his sincere gratitude to Mr. H. B. Parks, Botanist in Charge, S. M. Tracy, Herbarium, Agricultural and Mechanical College of Texas.

PLANTS REFERRED TO

For brevity and general readability, the common names of the plants listed below will be used in the text.

*Amargosa—*Castela texana* (T. & G.) Rose (Simarubaceae)
*Anacua—*Ehretia anacua* (Berl.) Johnston (Boraginaceae)
Ash—*Fraxinus* sp. (Olivaceae)
*Black brush—*Acacia rigidula* Benth. (Leguminosae)
*Brasil—*Condalia obovata* Hook. (Rhamnaceae)
*Capote—*Diospyros texana* Scheele (Ebenaceae)
*Catsclaw—*Mimosa biuncifera* Benth. (Leguminosae)
Cedar elm—*Ulmus crassifolia* Nutt. (Ulmaceae)
*Ceniza—*Leucophyllum texanum* Benth. (Scrophulariaceae)
Colima—*Xanthoxylum pterota* H. B. K. (Rutaceae)
*Coma—*Bumelia celastrina* H. B. K. (Bumeliaceae)
Composites (Compositae) including:
Helianthus sp. (mostly *angustifolius* L.)
**Parthenium Hysterophorus* L.
**Helenium microcephalum* D. C.
**Verbesina encelioides* (Cav.) Benth. and Hook.
*Coyotillo—*Karwinskia Humboldtiana* (R. & S.) Zucc. (Rhamnaceae)
Ebony—*Pithecolobium flexicaule* (Benth.) Coulter (Leguminosae)
*Giant opuntia—*Opuntia Lindheimeri* Engelm. (Cactaceae)
*Granjeno—*Celtis pallida* Torr. (Ulmaceae)
*Guajillo—*Acacia Berlandieri* Benth. (Leguminosae)
*Guayacan—*Porleieria angustifolia* (Engelm.) A. Gray (Zygophylliaceae)
*Gulf Coast guajillo—*Pithecolobium pallens* (Benth.) Cory
Hackberry—*Celtis laevigata* Wild. (Ulmaceae)

[1]Scientific article No. A200, Contribution No. 2116 of the Maryland Agricultural Experiment Station (Department of Entomology).

*Huisache—*Acacia farnesiana* (L.) Willd. (Leguminosae)
Huisachillo—*Acacia tortuosa* (L.) Willd. (Leguminosae)
**Lippia ligustrina* (Lag.) Britton (Verbenaceae)
*Lote—*Condalia obtusifolia* (Hook.) Weberb (Rhamnaceae)
*Lycium—*Lycium Berlandieri* D. C. (Solanaceae)
*Mesquite—*Prosopis juliflora* (Swartz) DeCandolle (Leguminosae)
*Mexican olive—*Cordia boisseri* D. C. (Boraginaceae)
*Mimosa—*Mimosa Lindheimeri* A. Gray (Leguminosae)
*Myrtle croton—*Bernardia myricaefolia* (Scheele) S. Wats. (Euphorbiaceae)
Palm—*Sabal texana* Bece. (Palmaceae)
*Palo verde—*Cercidium macrum* Johnston (Leguminosae)
**Phaulothamnus spinescens* A. Gray (Phytolaccaceae)
**Ptelea Baldwinii* T. & G. (Rutaceae)
*Retama—*Parkinsonia aculeata* L. (Leguminosae)
*Rock brush—*Eysenhardtia texana* Scheele (Leguminosae)
Screw bean—*Prosopis cinerascens* A. Gray (Leguminosae)
*Seaside croton—*Croton punctatus* Jacq. (Euphorbiaceae
*Soapberry—*Sapindus Drummondii* H. & A. (Sapindaceae)
Tasajillo—*Opuntia leptocaulis* D. C. (Cactaceae)
Tepehuaje—*Leucaena pulverulenta* (Schlecht) Benth. (Leguminosae)
Texas all-thorn—*Koeberlinia spinosa* Zucc. (Koeberliniaceae)
Tree catsclaw—*Acacia Wrightii* Benth. (Leguminosae)
*Vine minosa—*Mimosa malacophylla* A. Gray (Leguminosae)
Willow—*Salix* sp. (Salicaceae)
Yucca—*Yucca treculeana* Carr. (Liliaceae)

DESCRIPTIONS OF COLLECTING LOCALITIES

The distribution of the collecting localities is accurately shown on Fig. 1. For the sake of brevity, the numerical designations are used in the list. These localities represent a number of types of distinct floral associations, and a brief general description[2] of each of them seems pertinent.

Localities *1* through *10* are situated in the broad alluvial flood-plain and delta of the Rio Grande. Practically all of the land to the north of these localities is under cultivation.

Locality *1* is a portion of the narrow strip of short penetrable brush growing on the elevated places between the salt flats and meadows close to the coast. Mesquite, granjeno, ebony, yucca and giant opuntia predominate.

Locality *2* is a palm jungle interspersed with tepehuaje, Gulf Coast guajillo, anacua, ash, and ebony as well as a great number of vines and a variety of lower story woody and herbaceous plants.

Localities *3* and *4* are moderate-sized tracts of dense, mostly impenetrable chapparal averaging 15 to 20 feet in height and composed principally of Gulf Coast guajillo, ebony, mesquite, brasil, *Phaulothamnus, Lippia*, coma, giant opuntia, myrtle-croton, capote, Mexican olive and tree catsclaw. During 1946 collecting at *4* was confined to an area which was being hand-cleared.

Locality *5* is a dense forest 25 to 30 feet in height composed of tepehuaje, cedar elm, hackberry and anacua, all profusely adorned with Spanish moss. Further away from the river mesquite forestland succeeds.

*Based on determination by H. B. Parks.

[2]In each case the description applies only to areas in which collecting was actually carried out.

Locality *6* is a medium, mesquite forest (15 to 25 feet high) intermixed principally with lote, granjeno, giant opuntia, yucca and some blackbrush and huisachillo.

Locality *7* is a low lying government-maintained floodway which is largely covered with second growth mesquite and huisache, much of it weakened by high water table and salt.

Localities *8* and *10* are portions of an extinct and heavily silted river bed covered with a heavy stand of hackberry (25 to 40 feet high) interspersed with little underbrush as a result of pasturage. Spanish moss is common and in especially low places large willows frequently occur. Along the inland bank grows a heavy stand of anacua, ebony, elm and soapberry. This narrow strip of interesting flora grades into the heavy mesquite forest described next. A portion of *10* was being hand cleared during 1946.

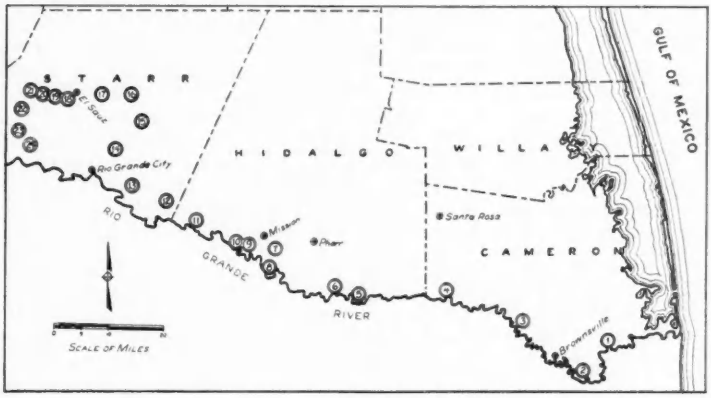


FIG. 1. Distribution of collecting localities.

Locality *9* is a heavy mesquite forest (20 to 30 feet high) intermixed with granjeno, giant opuntia, lote, colima, blackbrush, huisachillo, guajillo and coma. A large section of this area was cleared during the summer and fall of 1946.

Localities *11* through *24* are situated in the gently rolling upland region rising rather suddenly from the flood plain of the Rio Grande (considerably narrowed in this region). The soil is comparatively poor and good drainage creates semiarid conditions. As a result vegetation is stunted and sparse so that it is possible to walk almost anywhere with most vegetation within reach of net.

Localities *11* and *12* are two relatively low lying areas with mesquite, coyotillo, myrtle croton, ebony, coma, capote and colima predominating.

Locality *13* is atop one of the gravel-covered hills overlooking the Rio Grande flood plain. Its flora is composed almost exclusively of blackbrush, *Ptelea Baldwinii* and giant opuntia.

Localities *14* and *21* are exuberant growths of brush at the heads of dry land washes with coyotillo, rock brush, myrtle-croton and ***Lycium Berlandieri*** predominating. An extensive stand of cenzia surrounds area *14*.

Localities *15*, *19* and *22* are well-drained elevated areas covered largely by blackbrush, guajillo, giant opuntia and yucca together with some mesquite, granjeno, coyotillo, palo verde and lote.

Localities *16*, *17*, *18* and 20 are badly eroded dry-land washes supporting very little except decadent mesquite and in places the diminutive screwbean, also some granjeno and lote.

Locality *23* is a dry-land wash supporting principally mesquite, ebony, ***Mimosa biuncifera*** and colima.

Locality *24*, is a dry hillside covered principally with blackbrush, giant opuntia, ***Ptelea baldwinii***, lote, palo verde, mesquite and granjeno.

Huisache was found in abundance in all the localities described for Hidalgo and Cameron Counties. It usually occurs in pure stand in many places along the banks of the Rio Grande, along the edges of resacas and other low places that are so common throughout the broad alluvial flood plain south and east of Mission. It was usually in and around the habitat of the huisache that most of the flowering composites occurred which produced so many of the *Acmaeodera* reported here. In the uplands of Starr county, mesquite largely replaces huisache in the dry land washes which constitute the low lying areas. Just as in Hidalgo and Cameron counties, these low places when not too badly eroded, and especially when at the head of a dry land wash, supported the flowering composites on which *Acmaeodera* were collected.

ANNOTATED LIST OF BUPRESTIDAE COLLECTED[3]

1. **Polycesta velasco** Cast. *5* and *20*. May 17 through June 14. Fifteen specimens (only one of these from *5*) all on dead branches of decadent mesquite.

2. **Acmaeodera gibbula** Lec. *6*, *12*, *14*, *16*, *20*, and *22*. May 24 through July. Rather common, usually on or in flight near dead or dying branches of various shrubs, principally ceniza, mesquite and lote. Also on flowers of composites.

3. **Acmaeodera uvaldensis** Knull. *22*. April 6, 1947. Two males beaten from mesquite which was in bloom and fresh in leaf.

4. **Acmaeodera flavomarginata** Gray. *7*, *11*, *12*, *14* and Santa Rosa. September 29 through October. Common on flowers of composites, often in company with 5, 8, and 9.

5. **Acmaeodera macra** Horn. *7*, *11*, *12*, *14* and Santa Rosa. September 29 through October. Not common on flowers of composites, usually in company with 4, 8, and 9.

6. **Acmaeodera miliaris** Horn. *6*, *7*, *9*, *10*, and *11*. May 3 through July 4. Twelve specimens, all from flowers of composites.

7. **Acmaeodera flavinigrapunctata** Knull. *4*, *6*, *9*, *10*, *11* and *12*. May through June. Frequent on flowers of composites, often in company with 11.

[3]In this list, figures in italics denote collecting localities; those in roman print refer to species numbers in the annotated list of Buprestidae.

8. **Acmaeodera rubronotata** Cast. *7, 11, 12, 14* and Santa Rosa. September 29 through October. Common on flowers of composites, usually in company with 4, 5, and 9.

9. **Acmaeodera scalaris** Mann. *2, 3, 7, 11, 12, 14* and Santa Rosa. September through October. The most common of the fall *Acmaeodera*. Usually on flowers of composites and in company with 4, 5, and 8. Also occasionally found on fresh cut huisache.

10. **Acmaeodera obtusa** Horn. *6, 13, 19, 21,* and *22*. April 6 through May. Common mostly on flowers of giant opuntia.

11. **Acmaeodera pulchella** (Hbst.). *2, 4, 6, 10, 11, 12, 14, 19, 21,* and *22*. May 24 through July 4. An aberrant record was made at Santa Rosa when a single specimen was swept from flowers of a yellow aster on September 14, 1946. This species occurs usually on flowers of composites and is probably the most abundant *Acmaeodera* of the Lower Rio Grande Valley. In Hidalgo and Cameron Counties *pulchella* frequently was found on the same flowers with 7.

12. **Acmaeodera** sp. near **cribricollis** Horn. *24*. April 6, 1947. A single male specimen on foliage of *Ptelea Baldwinii*.

13. **Acmaeodera quadrivittata** Horn. *19*. April 12, 1947. A single specimen on flower of a small cereus cactus.

14. **Acmaeodera hulli** Knull. *20*. May 17, 1947. A single specimen on weakened granjeno. Two other specimens were observed that same day on granjeno at nearby *19*.

15 & 16. **Acmaeodera tubulus** (Fab.) and **A. neglecta** Fall. A series of 60 specimens selected from many hundreds seen in the field, includes what appears to be typical *tubulis* and typical *neglecta* but in between variants seem to run together. The variations involve size, robustness, confluency of maculations, luster, punctation, and hair and setal prominence. These *Acmaeodera* are widespread and common in occurance, having been found at just about all localities March through May on flowers of various types, especially those of cacti and composites.

17 & 18. **Acmaeodera** spp. near **gemina** Horn. *13, 19, 22,* and *24*. April 6 through May 3. Rare on flowers of cacti and on guajillo.

19. **Paratyndaris olneyae crandalli** Knull. *16, 17,* and *20*. May 3 through August. Frequent, especially during July and August, on dead branches of decadent mesquite. Also on dead branches of Rock brush. These beetles feed freely on the bark of dead branches, and they have been observed to cut deeply into the wood of dead terminal twigs.

20. **Paratyndaris chamaeleonis** Skinner. *4, 9, 12, 14,* and *16*. June, July and August. Frequent on dead branches of ceniza. Also ovipositing in dead mesquite branches; and on *Lycium Berlandieri*.

21. **Hippomelas sphenica** (Lec.). *9, 15, 16, 20* and Santa Rosa. September 15 through November. Very common on mesquite, especially on decadent and fresh cut trees where brush is being cleared. Females were often seen ovipositing in dead mesquite snags. These beetles seem to feed freely on mesquite foliage as evidenced by their copious green-colored fecula. Fresh emerged specimens lack the

characteristic yellow pulverulence which seems to be a secretion accumulating with age. Evidently pulverulence, as it generally occurs among the Buprestidae, is of this nature; therefore, the variations in the definition of the pulverulent markings in this family. It is pointed out, however, that the pubescence associated with such markings is apparently unaffected by age but rather by abrasion.

22. **Psiloptera drummondi** Cast. *13*, *14*, *15*, *22*, and *23*. June through November. Common, especially so in the fall and early winter on weakened coyotillo, guajillo, and blackbrush. A single specimen was collected on June 24 from Gulf Coast guajillo at *4*. These beetles characteristically feed on the twigs one to two inches from their tips, usually chewing them partly off. During October and November in heavily infested areas coyotillo conspicuously shows much dead terminal foliage and chewed and broken branch tips.

23. **Psiloptera cupreopunctata** Schffr. *3*, *4*, *8*, *9*, *10*, and Santa Rosa, September through November. During October and November very common on mesquite, huisache and occasionally on coma, especially where brush is being cleared. On mesquite this species has the habit of chewing the bark at the bases of leaf petioles in such a manner as to cut off the leaves. Heavily attacked trees may be almost completely defoliated. The fecula of this species is brown in color.

24. **Dicerca lurida** (Fab.). *8* and *10* May. Two specimens collected on dead willow. Also a number of dead specimens were cut from a dead willow trunk.

25. **Cinyra prosternalis** Schffr. *4*. June 22 through July. Eight specimens on capote. Emergence holes indicate that this species bores in the heart and sapwood of healthy capote. Often large amounts of gum exudes from the emergence holes and other mechanical injuries on these trees.

26. **Chrysobothris lixa** Horn. *18* and *24*. April 6 and April 12. Two males beaten from mesquite fresh in leaf.

27. **Chrysobothris pubilineatus** Vogt. *13*. April 6 through April 17. Three specimens collected on blackbrush. About five others were missed.

28. **Chrysobothris ephedrae** Knull. *22*. A single male April 6, 1947 on blackbrush. Two others were seen in company with 27 at *13* but these were missed.

29. **Chrysobothris prosopidis** Fisher. *4*, *6*, *7*, *10*, *12*, *13*, *19*, *22*, and *24*. April 6 through October (probably year-round). Common especially in the spring on blackbrush. Also on mesquite and huisache. Reared from dead branches of blackbrush collected at *13*.

30. **Chrysobothris basalis** Leconte. *1*, *2*, *3*, *4*, *5*, *6*, *7*, *9*, *10*, *11*, and *12*. March 31 through October (probably year-round). Common on fresh dead and dying huisache. Also occurs on mesquite occasionally. Adults have been cut from dead tepehuaje on one occasion, but this should be considered exceptional since this *Chrysobothris* is distinctly partial to huisache.

31. **Chrysobothris octocola** Leconte. Taken at practically all

localities, January 21 through November (probably year-round). Undoubtedly the most common buprestid of the area. Usually on fresh dead and dying mesquite. Also occasionally on huisache, huisachillo, tree catsclaw, and hackberry. This *Chrysobothris* is especially common about clearings and has been observed to swarm about smoldering mesquite legs.

32. **Chrysobothris purpureovittata** Horn. *6*, *9*, *20* and *22*. April 3 through August. Usually on lote in which it very probably breeds. Also on dead ebony, fresh cut huisache and decadent granjeno.

33. **Chrysobothris viridiceps** Melsh. *8* and *10*. May 15 through June. Common on fresh cut cedar elm in which this species breeds. Dead trunks riddled with characteristic-sized emergence holes, and adults cut from such trunks.

34. **Chrysobothris femorata** (Oliv.). *2*, *5*, *8* and *10*. May 15 through June and September. Common on fresh dead and dying hackberry as well as on willow. Adults have been cut from both these trees. Although occuring in abundance at the same time and locality, this species and the preceding do not mingle at all. Each of these species is very specific in selecting its host plant.

35. **Chrysobothris exesa** Leconte. *19*, *22*, and *24*. April 6 through April 17. Seven specimens, all from dead or dying branches of mesquite.

36. **Chrysobothris acuminata** Leconte. *6*, *9*, and *10*. April 7 through June 15. Not common, on weakened mesquite.

37. **Chrysobothris acutipennis** Chev. *2*, *3* and *4*. May 26 through June and September. Rather common on fresh cut ebony, Gulf Coast guajillo and tepehuaje. Reared from tepehuaje branches pruned by *Oncideres pustulatus* Lec. two seasons previously.

38. **Chrysobothris merkelii** Horn. *4*, *6* and *9*. May through June and January 15. Common on fresh dead and decadent ebony and Gulf Coast guajillo.

39. **Chrysobothris analis** Leconte. *1*, *2*, *3*, *4*, *6*, *7*, *9*, *10*, *13*, *16*, *20* and *22*. March 3 through November (probably year-round). Common on a variety of fresh dead and dying woody plants including huisache, ebony, guajillo, mesquite, granjeno, hackberry and cedar elm. Reared from tepehuaje, huisache and cedar elm.

40. **Actenodes flexicaulis** Schffr. *1*, *3* and *4*. April 13 through June 8. Of the eight specimens collected, five were on fresh dead or dying ebony. The remaining three were on brasil, granjeno and huisache, in the vicinity of ebony, however.

41. **Actenodes calcarata** (Chev.). *1*, *4*, *7* and *10*. June 8 through August 19. Common on weakened huisache. The adults chew the bark of smooth branches forming conspicuous "abraded" patches. A sluggish species easy to collect.

42. **Actenodes mendax** Horn. *6* and *20*. April 19 through July 9. Twelve specimens on decadent mesquite.

43. **Agrilus macer** Leconte. *2*, *8* and *10*. March 31 through June, August and September. Common on weakened and fresh dead hackberry trunks from which adults were cut on frequent occasions.

44. **Agrilus pulchellus** Bland. *9*, *22*, and *23*. May 3 and 17, and September 1. Three specimens all in flight close to the ground, no *Erigeron* observed nearby.

45. **Agrilus exsapindi** Vogt. *8* and *10*. March 31 through September 16. Frequent on foliage of soapberry early in the spring and occasionally thereafter. Adults emerged continuously, April through September, 1947 from a log chopped in April from a tree felled in the spring of 1946.

46. **Agrilus sapindicola** Vogt. *8*. March 31 through April 5. Common during the short period indicated on tender new foliage of soapberry in company with 45 and 47.

47. **Agrilus ornatulus** Horn. *8*. March 31 through April 5. Common during the short period indicated on tender new foliage of soapberry in company with 45 and 46. A single specimen was also taken during late August. This species is suggestive in appearance of the ant *Cryptocerus angustus* Mayr. which commonly occurs on the same shrubbery at this locality.

48. **Agrilus felix** Horn. *20*. April 6, 1947. A single female beaten from new mesquite foliage. Intensive collecting at this locality a week later failed to produce another.

49. **Agrilus obscurilimeatus** Vogt. *13*. April 6 through April 20. Eight specimens collected on two blackbrush shrubs growing close together beside the Rio Grande City-Mission highway.

50. **Agrilus cupreonitens** Fisher. *1*, *2*, *8*, *10* and *13*. March 17 through July 20. Three specimens on blackbrush at *13*. Three on mesquite and four on huisache at the remaining localities.

51. **Agrilus addendus** Crotch. *2*, *8*, *9*, *10*, *13* and Brownsville, March 17 through June 27, September. At *13* frequent on blackbrush remote from any huisache. At other localities mostly on huisache and occasionally on mesquite.

52. **Agrilus palmacollis** Horn. *7*, *8*, *9*, *22*, *24* and Brownsville, March 23 through April 15. Frequent beating succulent spring foliage of mesquite. Usually in company with 53.

53. **Agrilus prosopidis** Fisher. *3*, *7*, *8*, *9*, *22* and Brownsville, March 17 through April 15. Uncommon beating succulent spring foliage of mesquite. Usually in company with 52. A single female was taken on a dead ebony branch on July 27 at *4*.

54. **Agrilus neoprosopidis** Knull. *2*. February 14 through April 18. Frequent on fresh cut branches and foliage of tepehuaje. Reared from the same tepehuaje branches mentioned under 27.

55. **Agrilus acaciae** Fisher. *2*, *4*, *6*, *7*, *8*, *9*, *10* and 13. April 6 through September. Frequent at *13* on blackbrush remote from any huisache. Common at other localities on huisache. Reared and cut from dead huisache.

56. **Agrilus lecontei celticola** Fisher. *1*, *2*, *4*, *8*, and *10*. March 17 through August, but most common early in spring. At *1* and *4* several were taken on granjeno remote from any hackberry. At other localities common on hackberry. Also several from soapberry at *8*.

57. **Agrilus lacustris** Leconte. *2*, *4* and Boca Chica (along coast just north of the mouth of the Rio Grande). At Boca Chica common on seaside croton on October 19, 1946. At *2* and *4* on this same host plant during April and May.

58. **Agrilus eleanorae** Fisher. *13* and *19*. April 6 through April 19. Three specimens at *13* on blackbrush and three specimens at *19* on guajillo coppice.

59. **Paragrilus texanus** Schffr. *2*, *4*, *6*, *8*, *9*, *10* and *12*. March 7 through September, especially in the spring. Common and general in its occurrence. Beaten and swept from huisache, tepehuaje, mesquite and various herbs including callirhoe and other malvaceous plants. The fact that this species occurs frequently where malvaceous plants are absent would indicate it can be independent of them.

60. **Pachyschelus fisheri** Vogt. *4*. June through September 13. Frequent on foliage of myrtle-croton the leaf of which the larva mines. The larva first tunnels along the very margin of the leaf, often completely around, and then crosswise back and forth up one half and then down the other. Pupation takes place within the leaf in a cell lined with coarse silk of low tensile strength. In the course of rearing the *Pachyschelus*, the author frequently obtained instead a chalcidoid parasite which Mr. A. B. Gahan[4] has identified as *Spalachalcis* near *odontotae* (How.).

61. **Taphrocerus agriloides** Crotch. East of *5*. May 19, 1946. Common sweeping grasses and sedges along margin of a water hyacinth filled resaca.

62. **Taphrocerus Schaefferi** Nic. and Weiss. *2* and *10*. March and July. Sweeping grasses.

63. **Taphrocerus** sp. near **gracillis** Say. McAllen, July. Sweeping grasses.

ADDENDA

Recorded from the Lower Rio Grande Valley are seven species of Buprestidae which the writer did not find. Including these, the total number of species known from the area is increased to 70. These additional species are listed below together with two other Texas species which may occur in the Lower Rio Grande Valley.

64. **Cinyra robustus** Chamberlin (1920). Described from a single specimen labeled "Texas".

65. **Agrilus subtropicus** Schffr. Described from Brownsville. Also reported by Knull (1937) from the same locality as occurring on capote.

66. **Agrilus lautuellus** Fisher (1928). Reported from the following Texas localities: San Diego, Zavalla, County, Nueces River, Sabinal, Devil's River, Del Rio and New Braunfels; April, May and June.

67. **Agrilus obolinus** Lec. Reported by Knull (1944) as being collected on foliage of hackberry at Brownsville.

68. **Agrilus esperanzae** Knull (1935). Described from a single specimen collected at Brownsville.

[4]Division of Insect Identification, Bureau of Entomology and Plant Quarantine.

69. **Agrilus dolli** Schffr. Described from Brownsville and reported by Fisher (1928) to occur on ebony during May and June.

70. **Agrilus muticus** Lec. Fisher (1928) reports this species from Brownsville and numerous other Texas localities. Adults are said to occur on *Callirhoe involucrata* Gray.

71. **Agrilus viridescens** Knull (1935). Described from a series of specimens found on mesquite at Brownsville.

72. **Trigonogya reticulaticollis** Schffr. (1904). Described from five specimens collected at Brownsville by C. H. T. Townsend and Ottmar Dietz.

FAUNAL CHARACTERISTICS OF THE SPECIES

In the following table is given the general distributional categories of most of the species.

Occurring in the Southern Parts of New Mexico, Arizona, and California	Peculiar to the Rio Grande Valley and Adjacent Areas	Occurring in the Lower Austral and Succeeding Zones Northward
Polycesta velasco	Acmaeodera uvaldensis	Acmaeodera pulchella
Acmaeodera gibbula	macra	tubulus
flavomarginata	miliaris	neglecta
rubronotata	flavinigrapunctata	Dicerca lurida
scalaris	obtusa	Chrysobothris femorata
quadrivittata	Paratyndaris chamaeleonis	purpureovittata
hulli Knull	Psiloptera cupreopunctata	viridiceps
Paratyndaris olneyae	Cinyra prosternalis	Agrilus lecontei
Hippomelas sphenica	Chrysobothris pubilineatus	lacustris
Psiloptera drummondi	acuminata	obolinus
Chrysobothris lixa	acutipennis	Taphrocerus agriloides
ephedrae	Actenodes flexicaulis	schaefferi
prosopidis	Agrilus subtropicus	
basalis	macer	
octocola	exsapindi	
exesa	sapindicola	
merkelii	ornatulus	
analis	esperanzae	
Actenodes calcarata	obscurilineata	
mendax	cupreonitens	
Agrilus pulchellus	prosopidis	
felix	neoprosopidis	
addendus	acaciae	
palmacollis	dolli	
	viridescens	
	eleanorae	
	Paragrilus texanus	
	Pachyschelus fisheri	

It is evident from this table that the buprestid fauna is largely Sonoran in character with only twelve species having a distribution extending northward into the Lower Austral and succeeding Zones. As far as known, of the remaining 52 species, 28 are peculiar to the Lower Rio Grande Valley and southward, whereas the remainder are known to extend westward as well as undoubtedly southward in their distribution, thus representing Lower Sonoran forms as generally accepted.

HOST PLANTS ASSOCIATED WITH THE SPECIES

Except for most of the *Acmaeodera, Paragrilus* and *Taphrocerus* likely host plant associations have been made for most of the species of Buprestidae collected. A summary of these data is given in the following list:

Mesquite	18 spp.	Gulf Coast guajillo	2 spp.
Blackbrush	9	Cedar elm	2
Huisache	8	Capote	2
Ebony	6	Coyotillo	1
Hackberry	5	Willow	1
Granjeno	4	Ceniza	1
Tepehuaje	4	Lote	1
Soapberry	3	Seaside croton	1
Guajillo	3	Myrtle-croton	1

It is evident that several dominant woody plants serve to support the majority of the Buprestidae in this region. Aside from those listed above, a number of other dominant plants were found to be unproductive of buprestids despite close and frequent observation. These plants are as follows: *Mimosa Lindheimeri, M. Wootoni, M. biuncifera,* palo verde, retama, allthorn, colima, amargosa, brasil, ash, Mexican olive, anacua, guayacan and coma.

It is interesting to note that all of the 12 northern forms of Buprestidae are associated with host plants which likewise have a northern distribution or else have congeneric forms with a northern distribution. This same parallelism holds true with the buprestids ranging westward. On the other hand, only three of the species peculiar to the Lower Rio Grande Valley affect plants largely confined to the area; i.e., insofar as distribution northward and westward is concerned.

SEASONAL OCCURRENCE OF THE SPECIES

From the annotated list of species it is evident that the majority of the Buprestidae of the Lower Rio Grande Valley may be classed into a number of categories with regard to their seasonal occurrence. These categories represent those species occurring primarily in (1) early spring (February, March and April); (2) spring (April, May and early June); (3) early summer (May, June and July); (4) summer (June, July and August); (5) early fall and fall (September, and October); (6) fall and early winter (October, November, and December); (7) early spring through fall (April through October); and (8) year-round.

In general most of the *Agrilus* belong in (1) and (2), *Hippomelas* in (5) and (6), *Psiloptera* in (4), (5) and (6), *Polycesta* in (3), *Cinyra* in (4), *Actenodes* in (3), and *Pachyschelus* in (7). Some *Chrysobothris* belong in (1), others in (3) and (4), and still others in (7) and (8). The *Acmaeodera* break down into four short period groups, namely, those in (1), those in (2), those in (3), and those in (5).

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VIRAL AND RICKETTSIAL INFECTIONS OF MAN, edited by THOMAS M. RIVERS with 27 contributors. 587 pages, 31 charts, 46 figures and 6 plates in color. J. B. Lippincott Company, Philadelphia, London, Montreal. 1948. $5.00.

The field of viruses and rickettsia has for many years been in such a state of change that it was difficult for workers in other areas to maintain even a general picture of the diseases produced by these agents. As indicated in the preface of this work, it was the intent of the editor to bring together the opinions of outstanding workers in each group of these diseases. This has been admirably done and there is a great deal of general agreement that has been reached. Many of the older conflicting views have been reconciled in light of more recent developments so that altho there obviously remains a great deal to be learned, many of the obstacles have been partially or completely removed with some of the newer techniques. Since a large number of the viral diseases and the majority, if not all, of the rickettsial infections are transmitted from one host to another by insect or other arthropod vectors a work of this type will be of value to entomologists working in medical entomology and related fields. However, the entomological side of the problem receives little attention other than a listing of the known or suspected arthropods involved for a particular infection, with some brief mention of factors affecting natural and experimental transmission.

As indicated in the title, only diseases affecting man are covered, but these include diseases that rarely attack humans altho they may be common in other animals. An exception to this is the chapter on bacterial viruses or bacteriophages. Each disease is discussed under a number of subheadings including: Introduction, History, Clinical Picture, Pathological Picture, Etiology, Diagnosis, Treatment, Epidemiology, and Control Measures. The first six chapters are devoted to a general discussion and techniques used in the study of these agents, with a chapter on Epidemiology. These would be of particular value to workers from another field whose investigations might extend into this area.

Altho the book was primarily written for medical students and practicing physicians it should find a place on the desk of many research workers in adjoining areas. An excellent bibliography to recent work and the more pertinent older contributions is found at the end of each chapter. Because the publication of this text was subsidized by The National Foundation for Infantile Paralysis, it is sold at a price which will make it much more attractive to the individual who might wish to have a copy for occasional reference to subject matter mostly outside of his major interests. The low price is in no way a measure of the quality of the work or of the printing itself. The only criticism the reviewer finds, in view of the special nature and purpose of the text, is that more illustrations might have been provided in several of the chapters.—CHARLES H. DRAKE.

STUDIES ON THE INTERNAL ANATOMY OF THE BOX ELDER BUG, LEPTOCORIS TRIVITTATUS (SAY)

(Hemiptera, Coreidae)[1, 2]

TYLER A. WOOLLEY,
Department of Zoology, Colorado A. & M. College,
Ft. Collins, Colorado

INTRODUCTION

The box elder bug, *Leptocoris trivittatus* (Say), has been of interest to the writer for some time since representatives of Hemiptera are known to exhibit a diversity of internal structures. The writer undertook the problem of studying the internal morphology of this insect out of curiosity and a general interest in morphology.

MATERIALS AND METHODS

Insofar as possible dissections were made on live insects which had been injected with a vital stain. In the latter technique trypan blue was found to give the best results of a series of stains used and required a minimum of time to become effective. Levy's solution was used to wash off excess stain and to cover dissected insects.

Kahle's and Carnoy's solutions were employed to fix whole insects and dissected organs. The latter were washed and preserved in seventy per cent alcohol. Fixed insect and tissues were dehydrated in alcohol, cleared in xylene and imbedded in paraffin. Sections of the imbedded materials were cut at 5, 7, and 10 microns.

The histological stains used in the problem included Delafield's hematoxylin, fast green (FCF), Hansen's trioxyhematin, Heidenhain's iron hematoxylin and picro-fuchsin.

The drawings of gross structures were made free-hand. The writer used both dissected specimens and stained whole mounts for this purpose. All histological drawings were made with the aid of a camera lucida. The details of the drawings were filled in after a general outline had been made.

THE DIGESTIVE TRACT AND ASSOCIATED STRUCTURES

Breakey (1936), Hood (1937) and Harris (1938) in describing the digestive structures of various Hemipterans, list the regions of the digestive tract of these insects in slightly different ways, but all of them demonstrate the same general regions and areas of the alimentary canal.

Elson (1937) divides the alimentary canal of *Leptocoris* into the three principal regions generally designated in insects and states that

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[1]Part of dissertation presented for degree of Doctor of Philosophy, Department of Zoology and Entomology, The Ohio State University.

[2]Sincere appreciation is extended to Dr. Clarence H. Kennedy, for his encouragement and support of the work. The author also expresses his deep gratitude to Mr. George F. Edmunds, Jr., and Miss Alvira Woolley, who supplied insects used in the study.

the digestive tract of this insect "is of moderate length, being approximately twice the length of the body."

In this paper the alimentary tract of *Leptocoris* is divided into the following regions:

I. STOMODAEUM
  Pharyngeal Pump (Cibarium)
  Pharynx
    Salivary Glands
  Oesophagus
II. MID-INTESTINE
  1st Stomach (M_1)
  2nd Stomach (M_2)
  3rd Stomach (M_3)
  4th Stomach (M_4)
III. PROCTODAEUM
  Ileum
    Malpighian Tubule Diverticulae
    Malpighian Tubules
  Rectum
    Rectal Diverticulum (cul-de-sac)

The Stomodaeum

The pharyngeal pump is a sclerotized, wedge-shaped tube, which has an inverted dorsal ridge for about one-third its length. The pharyngeal pump then becomes tubelike (Plate II, figs. 2, 3) and merges with the pharynx. The pharynx is widened at its anterior end but tapers at its caudal extremity before the union with the oesophagus immediately posterior to the brain (Plate II, figs. 2, 4). At this junction the pharynx exhibits a slightly bulbous portion (Plate V, fig. 18) which has muscle attachments distinct from those of the pharyngeal pump. This pair of muscles projects laterally from each side of the bulb and attaches to the apodemes of the head.

Dilation of the pharyngeal pump is accomplished by two sets of muscles attached to its dorsal ridge. The elasticity and inverted shape of the sclerotized portion of the pump are sufficient to return the pump to its trough-like shape (Plate II, fig. 2) and while the writer assumes these muscles to be adequate for the pharyngeal pumping action, it appears that the small set of muscles at the distal dilation of the pharynx function in an auxiliary fashion. This assumption is further substantiated by noting that the bulbous portion of the pharynx is found posterior to the brain. The narrowed end of the pharynx extends through the brain before it joins the thin-walled oesophagus. This smaller set of muscles implies an added force behind the anterior dilator muscles of the pharyngeal pump in forcing or moving fluids through the pharynx to the oesophagus.

The Salivary Glands

There are two pairs of salivary glands in the box elder bug, the primary and the accessory glands. The primary salivary glands are large, four-lobed structures lying in the cavities of the lateral portions of the metathorax and the first abdominal segments. These glands are translucent and whitish in color, their lobes slightly irregular in shape.

In a cluster of the lobes the anterior and posterior extensions are wiener-shaped and elongated while the lateral lobes are pyriform or rounded (Plates I & V, figs. 1, 18). From each cluster a long cylindrical salivary duct extends cephalad. Each salivary duct lies ventral to the oesophagus and terminates in a common duct. The latter enters the salivary syringe (Plate V, fig. 18), but one notes that in histological section (Plate II, fig. 4) the two ducts remain separate for some distance in the ventral portion of the syringe before they fuse. In gross dissection the common duct appears single.

Adjacent to each salivary duct and easily confused with it, is an elongated, slightly coiled tube, the accessory salivary gland (Plate V, fig. 18). This narrow, cylindrical gland empties into the duct entrance of the principal salivary gland (Plate V, figs. 21, 22). The accessory gland extends forward into the thorax and head, where the gland turns and extends posteriorly. The free end of the accessory gland lies in the thoracic cavity.

The salivary syringe is a chitinous, cylindrical structure (Plates I, II, V, figs. 1, 2, 19). The syringe lies ventral to and connects with the pharynx at its anterior end. Elson (1937) describes the salivary pump as a distinguishing characteristic of phytosuccivorous forms of Hemiptera.

The posterior wall of the salivary syringe is invaginated and forms a piston-shaped structure. The syringe is dilated by a set of muscles attached to the posterior extension of this piston by a tendonous attachment. The dilator muscles have their origin on the tentorium near the rear of the cranial cavity (Plate II, fig. 2).

The oesophagus is short and thin-walled. It lies in the general neck region, and while it is difficult to determine exactly where the organ ends in gross section when the stomach is deflated, histologically the oesophagus is seen to end in a valve-like constriction. The latter is somewhat like the one described for *Anasa tristis* by Breakey (1936). At this point the oesophagus joins the large ventriculus or stomach (M_1, figs. 1, 2, 6).

The Mid-Intestine

The ventriculus or stomach proper (M_1) is situated in the thorax between the lateral masses of thoracic muscles; it is large and sac-like. The ventriculus extends from the prothorax to the region of the second abdominal segment and lies above the ventral ganglia. When the ventriculus becomes dilated, it fills the thoracic cavity. The walls of the ventriculus are frequently folded when it is empty. The longitudinal compression is accomplished by two strands of longitudinal muscles running the length of the ventriculus and forming a dorsal and ventral median raphe (Plate I, fig. 1).

The ventriculus or first stomach narrows abruptly into a tubular portion of the mid-intestine, the second stomach (M_2), which is directed anteriorly. The second stomach extends to the area of the first abdominal segment, turns abruptly caudad and joins the enlarged, slightly inflated portion of the mid-intestine, the third stomach (M_3). The latter becomes constricted at its posterior end and merges with the fourth stomach (M_4). The fourth stomach is short and bulbous and joins the

ileum. At this junction the histological structure appears valve-like, which will be discussed later. The fourth stomach normally bears gastric caecae, but there are none in *Leptocoris*. Both Elson (1937) and Breakey (1936) point out, however, that *Anasa tristis*, a member of the same family, Coreidae, has these structures.

The Proctodaeum

The ileum, between the rectum and the mid-intestine proper, is a short and balloon-like region in the live insect. Glasgow (1914) describes the ileum in all species, but Snodgrass (1935) questions the use of the term in insect anatomy.

A pair of diverticula is produced laterally from the ileum. Four Malpighian tubules attach to these diverticula, two tubules arising from a common stalk or peduncle leading to each diverticulum. The tubules are coiled on the dorsal inner surface of the abdominal cavity, entwining themselves around the alary muscles of the heart, through the openings in the dorsal diaphragm and between the surrounding fat bodies.

EXPLANATION OF PLATE I

FIG. 1. Ventral view of displaced digestive system, salivary glands and Malpighian tubules (semi-diagrammatic).

ABBREVIATIONS USED ON PLATES

AC GL—accessory gland
ANT NV—antennal nerve
AO—aorta
BR—brain
CA—corpus allatum
C MS—circular muscle
C SAL D—common salivary duct
DIL MS—dilator muscle
E CL—egg cell
EJ D—ejaculatory duct
E NU—egg nucleus
EPTH—epithelium
F B—fat body
FOL—follicle
GNG—ganglion
GRM—germarium
IL—ileum
INT—intima
L MS—longitudinal muscle
LU—Lumen
M_1—ventriculus proper; first stomach
M_2—second stomach
M_3—third stomach
M_4—fourth stomach
M T—Malpighian tubule
M T DIV—Malpighian tubule diverticulum
N—nucleus
NR CL—nurse cell
NR TB—nutritive tube
OC—ocellus
OD L—lateral oviduct
OD M—median oviduct
OES—oesophagus
OVL—ovariole
PED—pedicel
PHAR PMP—pharyngeal pump; cibarium
PIS—piston
P-MS-TH-GNG—pro-mesothoracic ganglion; ("central ganglion")
PROT—protozoa
PR VLV—proctodaeal valve
P SAL GL—principal salivary gland
P-TH-GNG—prothoracic ganglion
PT M—peritoneal membrane
REC—rectum
REC DIV—rectal diverticulum
SAL D—salivary duct
SAL SYR—salivary syringe
S B—striated border
SEC—secretion
S LIG—suspensory ligament
SPD—spermatid
SPT—spermatheca
SPZ—spermatozoa
ST VLV—stomodaeal valve
S V—seminal vesicle
TENT—tentorium
TR—trachea
VAC—vacuole
V D—vas deferens

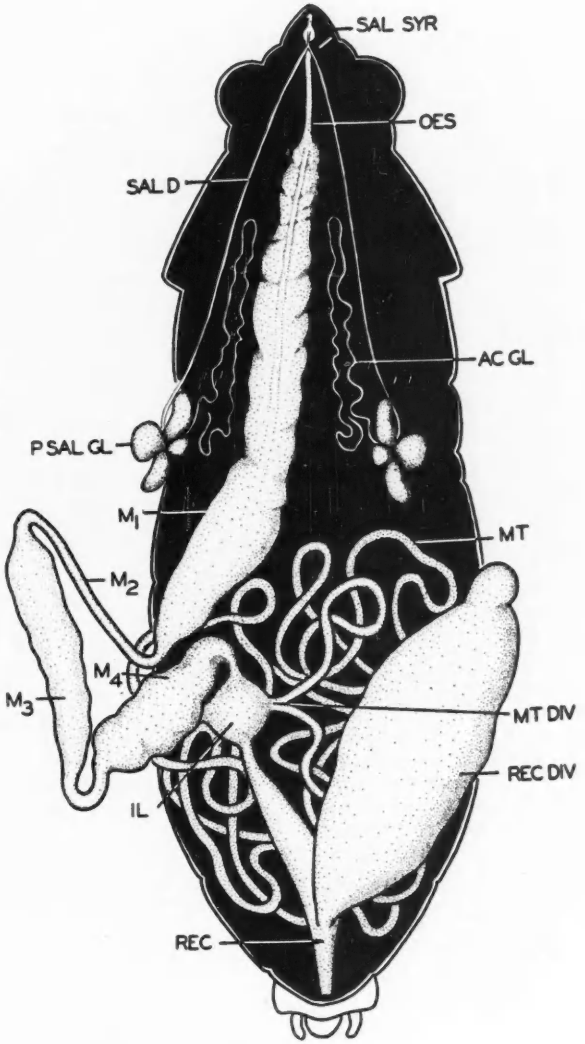

FIG I

The duct or lumen within the semi-transparent tubules appears to be spiralled. The orange-colored contents of the tubules were observed by the writer to pass down the ducts in an irregular, wave-like motion along a spiral path. Later histological studies of the Malpighian tubules revealed an arrangement of cells which formed a spiral duct (Plate IV, fig. 15).

The movements of the contents of the tubules suggests a muscular action within the tubules similar to peristalsis. However, Harris (1938) states that he found no muscle in the Malpighian tubules of *Murgantia histrionica* and the writer did not observe any in *Leptocoris*.

The ileum is connected directly to the rectum, which has a ventral diverticulum or cul-de-sac. The rectal sac is blind and is normally rather small. However, it may become distended and may nearly fill the abdominal cavity (Plate I, fig. 1). This sac and the rectum usually contain many protozoa. The writer does not intend, however, to describe these symbionts inasmuch as a work has been published on that problem by Kay (1942).

HISTOLOGY OF THE DIGESTIVE TRACT AND ASSOCIATED STRUCTURES

Stomodaeum

The pharyngeal pump and the pharynx are composed of hypodermal cells which stain very darkly, and a thin, clear intima. The same general histology is noticeable in both the pharyngeal pump and the pharynx from the anterior, trough-like area of the former to the junction of the pharynx with the oesophagus.

The bulbous portion of the pharynx posterior to the brain is surrounded by several bands of circular muscles. The arrangement of these muscles is suggestive of a sphincter.

The Salivary Glands

The main salivary glands of the box elder bug consist of four lobes (Plates I, V, figs. 1, 18). Each lobe is surrounded by a thin membrane and the entire cluster is enclosed in a thin sheath of tissue. These encasement tissues are the same for all lobes. They are thin and have scattered, elliptical nuclei. In this regard the box elder bug resembles the squash bug, described by Breakey (1936).

The epithelium of the principal glands is cuboidal, and all of the cells of the four lobes are similar. The nuclei of the cells are large and in some instances there were more than one within a cell. The cytoplasm of the salivary epithelium is extremely granular and stains very darkly. The inner border of the cells is much darker than the remaining

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EXPLANATION OF PLATE II

FIG. 2. Sagittal section of head and prothorax, showing position of internal organs. FIG. 3. Cross section of the pharyngeal pump anterior to the brain (semi-diagrammatic). FIG. 4. Cross section of the pharyngeal pump and salivary syringe. FIG. 5. Cross section of the oesophagus posterior to the brain. FIG 6. Longitudinal section of the stomodaeal valve, showing area of chitinous secretion.

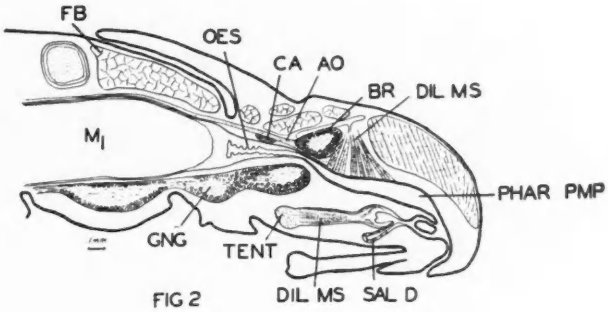

FIG 2

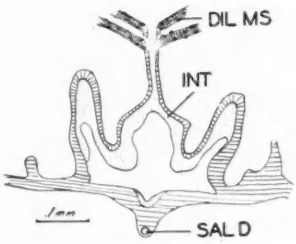

FIG 3

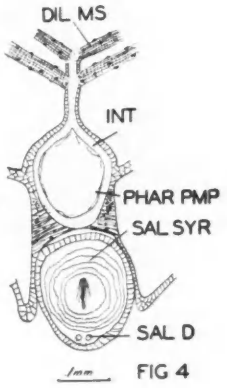

FIG 4

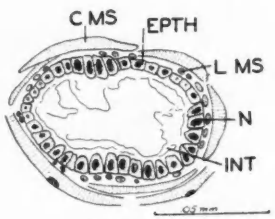

FIG 5

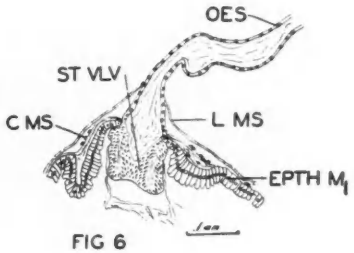

FIG 6

portion. The inner border of the salivary epithelial cells resembles the striated epithelium of the mid-intestine (M_3).

The salivary duct and the accessory salivary gland both have heavy, chitinous intimas (Plate V, fig. 20). In section the writer was unable to distinguish between the salivary duct and the accessory gland. The cuboidal cells of the two are identical and form a compact ring around the intima. The nuclei of the cells are round and the cytoplasm appears striped. The strands of the striping extend perpendicular to the axis of the ducts. A thin peritoneal sheath invests both the accessory gland and the salivary duct. This peritoneal sheath is continuous with the covering of the principal glands.

The salivary ducts and the accessory glands fuse at a common junction in a ring of cells in the principal gland. The writer has designated this ring of cells as the common salivary duct. The intima of the latter is continuous with the intimas of the accessory gland and the salivary duct. The ring cells of the common duct are cuneiform. They are wider at the base than at the lumen ends. The nuclei of the ring cells are small and basally located. The cytoplasm of these cells is clear.

The oesophageal epithelium begins immediately posterior to the band of muscles described around the bulbous portion of the pharynx. A cross section of the oesophagus in this region posterior to the brain shows a shallow intima of chitin with an encircling layer of epithelial cells. The epithelial cells are cuboidal in shape. They contain large, ovoid nuclei (Plate II, fig. 5). They rest on a thin basement membrane outside of which are the layers of longitudinal and circular muscles, respectively. The circular muscles predominate and are fewer in number than those encircling the bulbous portion of the pharynx.

The stomodaeal valve of the box elder bug (Plate II, figs. 2, 6) is rather well defined in histological section, but the cells are poorly differentiated from either the oesophagus or the mid-intestine. Because of the folds of the epithelium at this point, it is difficult to get a section which shows more than the syncitial-appearing arrangement shown in fig. 6. The nuclei are rather close together and appear very similar in shape and arrangement to the nuclei of the proctodeal valve (Plate IV, figs. 13, 14, 16). The stomodaeal valve is a many-folded projection of the stomodaeum into the mid-intestine at the junction of the oesophagus and the ventriculus (M_1). At this point the epithelium of the oesophagus is met by the columnar epithelium of the ventriculus.

From the ring of cells formed in the fold of the stomodaeal valve there is a slight secretion of chitin evidenced. As indicated in figure 6, however, this chitin extends only a short distance. It resembles an

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EXPLANATION OF PLATE III

FIG. 7. Cross section of epithelium of distended ventriculus (M_1). FIG. 8. Cross section of epithelium of normal, undistended ventriculus (M_1). FIG. 9. Epithelial cells of the second stomach (M_2) showing protozoa in the lumen. FIG. 10. Cross section of third stomach (M_3), showing epithelium with striated border and vacuoles. FIG. 11. Epithelium of M_3 enlarged to show striated border and vacuoles. FIG. 12. Longitudinal section of Malpighian tubule diverticulum, showing transition of epithelial cells.

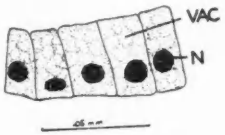


FIG 7

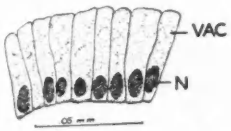


FIG 8

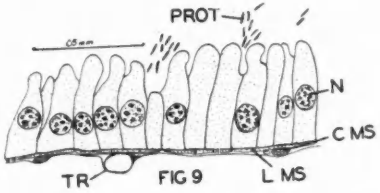


FIG 9

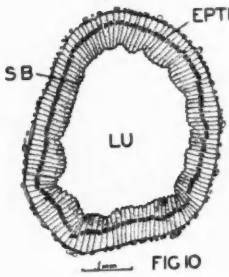


FIG 10

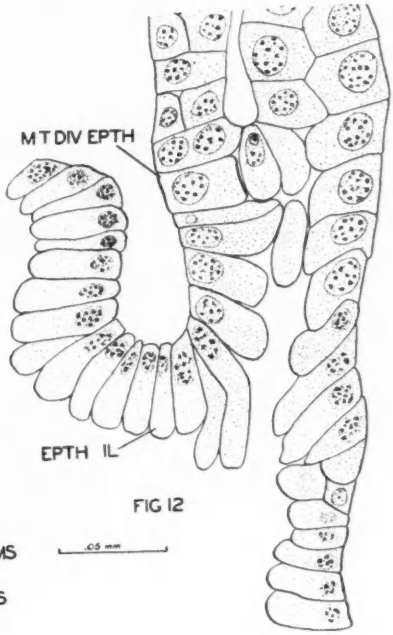


FIG 12

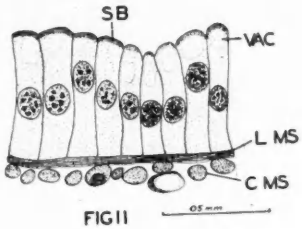


FIG 11

arrested membrane and might be a remnant of the peritrophic membrane although no developed peritrophic membrane was found in the box elder bug.

The writer would suppose that these cells at the junction of the stomodaeum and the ventriculus indicate an area in which a peritrophic membrane may have been secreted. It is also interesting to note that the junction is similar to the one described for *Anasa tristis* by Breakey (1936).

Mid-Intestine

The cells of the ventriculus or stomach proper (M_1) are quite different from the cuboidal epithelium of the oesophagus. The ventricular epithelium cells are columnar and vacuolated. The nuclei of these cells are oval and the cytoplasm is granulated.

When the stomach is inflated or has become distended by the ingestion of food or air, the cells lose their typical columnar shape. They become distorted into near-cuboidal contours; the nuclei become round. The general appearance of the nuclei and the cytoplasm otherwise remains about the same.

The distensibility of the ventriculus is remarkable. The writer has noted that it may occur by means of the intake of air by the insect. Some of the fixed specimens and the fresh insects used in dissections demonstrated large air bubbles distending the stomach to about twice the normal size.

The epithelium of the second, more tubular portion of the mid-intestine, the second stomach (M_2), is rather unique (Plate III, fig. 9). The cells are columnar and their distal ends are distorted to form crypts and pockets between the cell boundaries. In these entad or lumen pockets there are numberous protozoa. These organisms appear to be the same type found in the more posterior regions of the digestive tract, the ileum and the rectum.

The nuclei of the epithelial cells of the second stomach are round and the cytoplasm is only slightly granular. The longitudinal and circular muscles are opposite in arrangement to those of the ventriculus. The circular muscle layer is outermost, which is the reverse of the arrangement of the muscle layers of the ventriculus.

The third portion of the mid-intestine, the third stomach (M_3), is the only area of the digestive tract in which the writer found epithelium with a distinct striated border. The cells of this region are columnar with circular, centrally placed nuclei. The entad ends of the cells are vacuolated. Usually there is one large vacuole present in the distal end of each cell (Plate III, figs. 10,11).

The fourth portion of the mid-intestine, the fourth stomach (M_4), and the ileum (Plates I, IV, figs. 1, 13, 16) have columnar epithelium.

EXPLANATION OF PLATE IV

FIG. 13. Tangential section of ileum, Malpighian tubule diverticulum and rectum. FIG. 14. Cross section of the proctodaeal valve. FIG. 15. Cross section of Malpighian tubule. FIG. 16. Vertical section of ileum, Malpighian tubule diverticulum and rectum, showing proctodaeal valve. FIG. 17. Portion of the proctodaeal valve showing transition of epithelium.

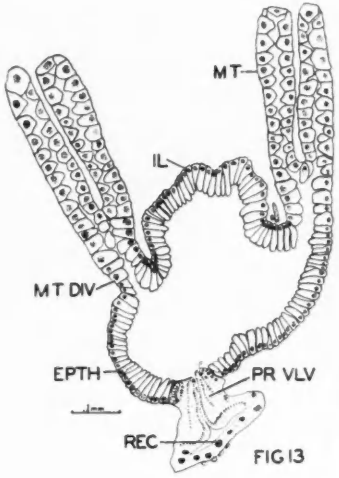


FIG 13

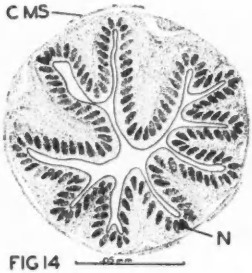


FIG 14

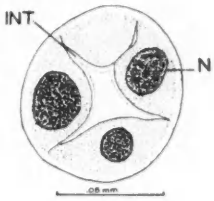


FIG 15

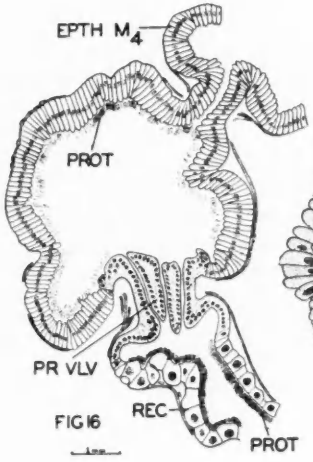


FIG 16

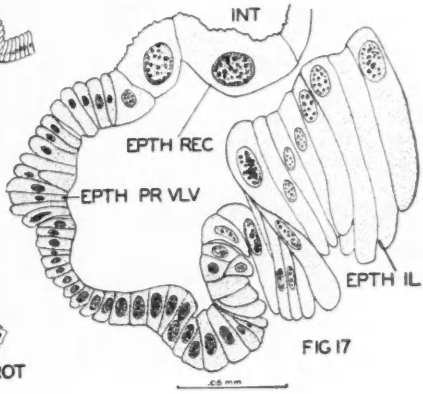


FIG 17

The lumen ends of the cells are light in color and the nuclei are more generally central in location.

The writer assumes that the layers of epithelium between the fourth stomach and the ileum might function as a valve (Plate IV, fig. 16). This valve may function in the control of food material passing into the ileum and may restrict the movement of large numbers of protozoa anteriorly to the mid-intestine. No protozoa were observed in the fourth stomach, although a few were noted in the second portion of the mid-intestine (M_2), which has crypts in the epithelium.

Proctodaeum

The ileum of the box elder bug is a spherical structure. It marks the junction between the mid-intestine and the rectum. The ileum is the organ from which the Malpighian tubule diverticula extend.

It is interesting to observe that the two pairs of Malpighian tubules in the box elder bug share a common stalk or attachment to the ileum. Breakey (1936) describes these tubules in *Anasa tristis* with separate attachments for each tubule. Hood (1937) and Harris (1938) indicate the condition of separate attachments also.

Just as interesting is the histology of this particular region. The epithelium of the junction of the Malpighian tubules with the ileum is distinctive. The shape of the epithelial cells at the junction of the ileum and the Malpighian tubule diverticula changes abruptly (Plates III, IV, figs. 12, 13, 16). There are columnar cells in the ileum, near-columnar to cuboidal cells in the diverticula and cuboidal or polygonal cells in the tubules.

Within the lumen of the ileum there are numerous protozoans near the lumen ends of the cells. These protozoans are also found in the rectum. The organisms seem peculiar to the ileum and the rectum, although a few have been mentioned previously in this writing in the second stomach (M_2). The work by Kay (1942) describes them.

Malpighian Tubules

The cells of the Malpighian tubules (Plate IV, fig. 15) are polygonal or cuboidal in shape. The nuclei are large and stain much darker than those of the digestive tract. The cytoplasm of the tubule cells also stains darker than usual and contains many inclusions.

The cells are arranged in a triangular or tripod arrangement. Two cells on one side of the tubule oppose a third cell across from them. The latter cell is slightly offset proximad or distad of the other two. Such an alternation of the cells of the tubule would account for the spiralling of the inner duct described earlier by the writer.

EXPLANATION OF PLATE V

FIG. 18. Lateral view of dissected pharynx, salivary syringe and salivary glands (semi-diagrammatic). FIG. 19. Ventral view of dissected salivary syringe and piston. Fig. 20. Cross section of salivary duct. FIG. 21. View of portion of principal salivary gland, showing common duct of salivary duct and accessory gland. FIG. 22. Cross section of principal salivary gland showing epithelium and common duct opening.

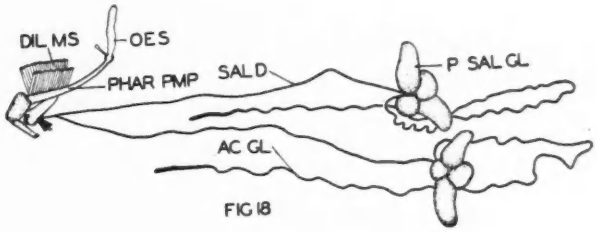


FIG 18

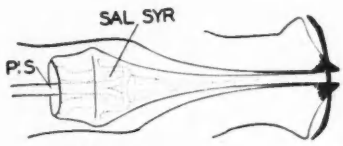


FIG 19

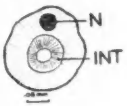
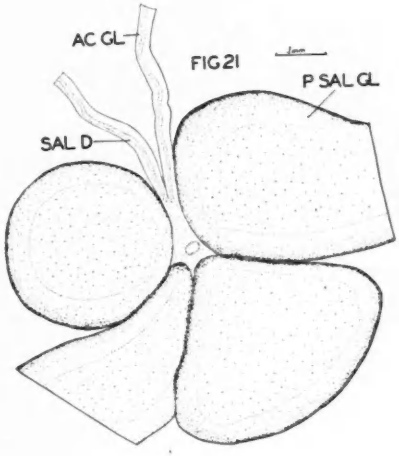


FIG 20



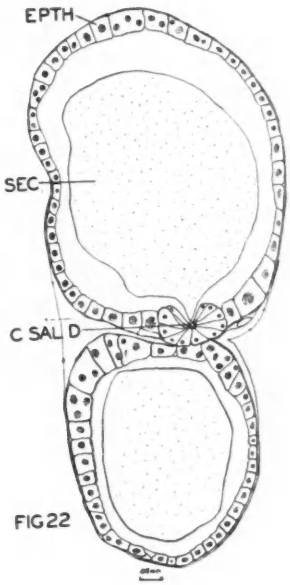


FIG 22

The cells are enclosed by a tight basement membrane. Their inner margins have a clear, thin intima. A striated border, so typical of Malpighian tubules of many insects, was not observed in *Leptocoris*. However, Wigglesworth (1947) states that fixation of these structures renders the border invisible, hence these tubules may have such a border, but the writer has not observed it.

At the junction of the ileum and the rectum there is a distinct valvular arrangement of cells which the writer has called the proctodaeal valve. The epithelium of the structure is folded inwardly and forms a narrow opening. The lumen of this valve appears somewhat rosette-shaped (Plate IV, figs. 13, 14, 16). Between the folds of the valve and the epithelium a connective tissue was observed. This was the first of this type of tissue found by the writer in the digestive tract of *Leptocoris*.

The epithelium of the proctodaeal valve is differentiated from both the epithelium of the ileum and that of the rectum (Plate IV, fig. 17). The cells of the valve are low columnar or cuboidal, smaller than the cells of either the ileum or the rectum, and stain darker than either of the other types of cells. The nuclei of the valve epithelium are distinctly ovoid or tear-drop in shape. The cell membranes are indistinct in many portions of the valve, especially in the cross section (Fig. 14). The connective tissue which lies outside the epithelium appears in long strands. The epithelial cells rest on a thin basement membrane and muscular elements of both circular and longitudinal types are noticeable. The longitudinal muscles are more prevalent than the circular muscles.

The rectum in the box elder bug is differentiated into two distinct regions, the rectum proper and the cul-de-sac or the rectal diverticulum (Plate I, fig. 1). Both of these structures have the same histological makeup.

The epithelium of the rectum and rectal diverticulum is made up of large cells with large nuclei. The inner margins or lumen edges of the cells show a chitinous intima. The latter is similar to the intima of the oesophagus (Plate IV, fig. 17). The inner margins of the cells appear to be trough-like and the protozoa previously mentioned are copiously packed in these trough-like folds (Plate IV, fig. 16).

THE FEMALE REPRODUCTIVE SYSTEM

Essig (1942) states that the female Hemiptera have from four to seven ovarioles, a spermatheca and two or three accessory glands. The ovaries of the order Hemiptera are typically acrotrophic or telotrophic, i.e., the nurse cells are located at the apex of the ovarioles. The spermatheca and the accessory glands may be globular or tubular.

EXPLANATION OF PLATE VI

FIG. 23. Longitudinal section of ovariole, showing egg cells, nutritive cells and tubes, and follicle. FIG. 24. Dorsal view of oviducts and spermatheca. FIG. 25. Longitudinal section of oviduct wall. FIG. 26. Ventral view of female reproductive organs.

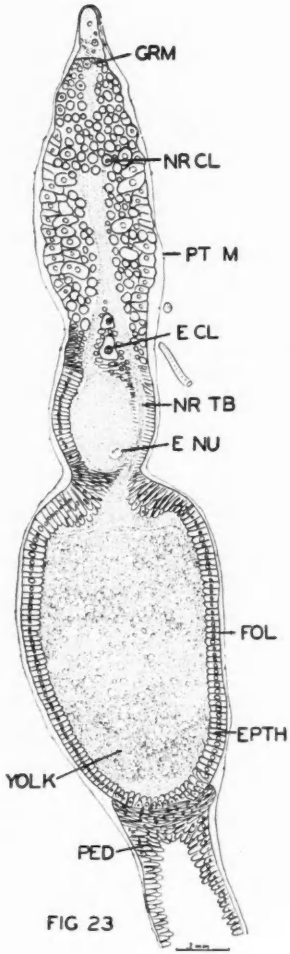


FIG 23

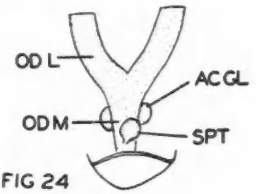


FIG 24

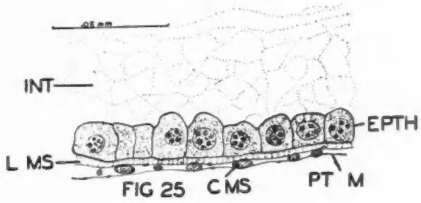


FIG 25

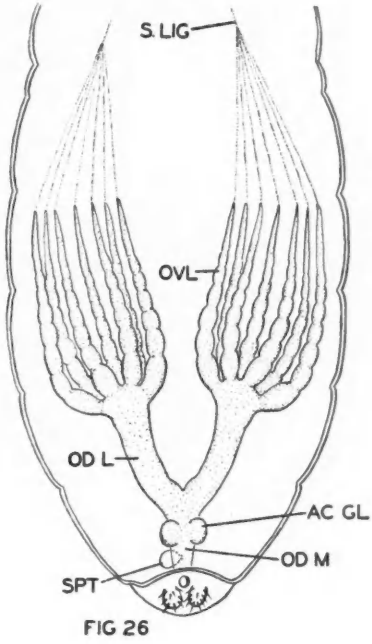


FIG 26

The yellow-colored ovaries of *Leptocoris* have seven ovarioles (Plate VI, fig. 26). These ovarioles are clustered about the anterior portions of the two lateral oviducts in a radial manner, so that when the terminal filaments are broken or cut, the ovarioles tend to resemble the spokes emanating from the hub of a broken, rimless wheel. The terminal filament of each ovariole joins adjacent filaments anteriorly to form a suspensory ligament. This ligament attaches to the dorsal body wall of the prothorax. The single suspensory ligament holds the ovarioles in a cone-like arrangement. The base of the cone thus formed is continuous with the lateral oviducts. The suspensory ligaments support the ovaries in the body cavity. However, the main support of the ovaries in *Leptocoris* is furnished by the numerous tracheae from the second abdominal spiracle. There are eleven such branches emanating from the trachea of each of the second abdominal spiracles.

The two lateral oviducts fuse posteriorly to form a common, median oviduct, which extends to the outside by way of the gonopore. The median oviduct bears dorsally the bulbous spermatheca which is attached to the oviduct by a short stalk (Plate VI, figs, 24, 26). There are two bulbous accessory glands attached slightly anterior and ventral to the location of the spermatheca on the median oviduct. These glands, which are assumed to function in egg laying, attach to the median or common oviduct by short peduncles.

THE HISTOLOGY OF THE FEMALE REPRODUCTIVE SYSTEM

The ovarioles of *Leptocoris* conform to the general pattern indicated by Riley (1907), Snodgrass (1935) and Wigglesworth (1947). The ovariole consists of a terminal filament, a germarium and a zone of growth or vitellarium. Riley includes all three, Snodgrass unites the latter two and Wigglesworth adds an *ovariole stalk* to the former three.

The terminal filament of *Leptocoris* is formed by connective tissue in a sheath which also surrounds the ovarioles and is continuous with the covering of the ovary.

The germarium is set off from the terminal filament by a distinct membrane, according to Riley (1907), and contains germ cells exclusively. There is such a membrane in *Leptocoris* (Plate VI, fig. 23), although there are also nurse cells in the apical end of the ovariole.

The nurse cells are found in the distal portion of the ovariole. Long strands or cords of material project from them to the developing oocytes in the follicular portions of the ovarioles (Plate VIII, fig. 30). The nurse cells and the germ cells make up the apical portion of the ovariole.

Each oocyte is enclosed by follicular epithelium and becomes larger as it moves down the egg tube toward the oviduct. An oocyte contains an abundance of nutritive material which stains darkly. The nucleus

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EXPLANATION OF PLATE VII

FIG. 27. Longitudinal section of male accessory gland and ductus ejaculatorius. FIG. 28. Longitudinal section of vas deferens and seminal vesicle, showing muscular elements and epithelium of seminal vesicle. FIG. 29. Longitudinal section of testis, showing three follicles and anterior portion of vas deferens. FIG. 30. Male reproductive organs, ventral aspect.

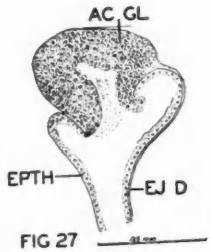

FIG 27

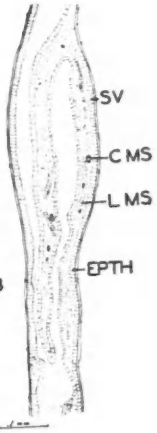

FIG 28

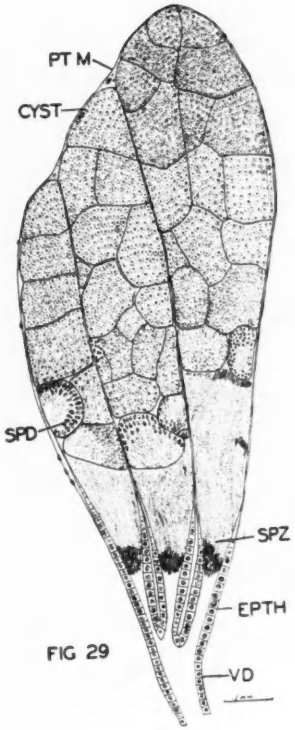

FIG 29

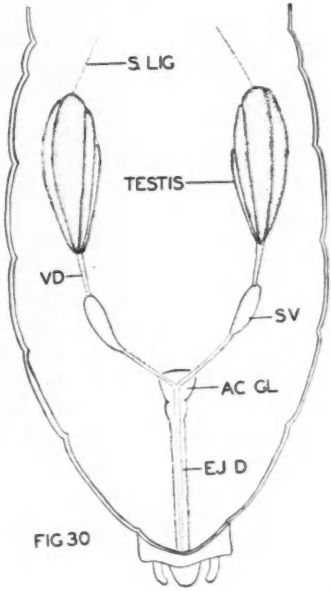

FIG 30

of the oocyte is found in the basal portion of the cell, (Plate VI, fig. 23). It is round, translucent and only slightly pigmented, and contrasts markedly with the nutritive element of the oocyte.

The follicular epithelium surrounding the oocytes rests on a thin basement membrane. The cells of this follicular epithelium are columnar except at the ends of the oocyte, where they become flattened and resemble stratified squamous cells. The nuclei of the follicular cells stain darkly and are centrally located. The nuclei are rounded in the columnar cells and oval in the flattened cells. The cytoplasm of the follicular cells is extremely granular. The writer assumes the follicular epithelium of *Leptocoris* to be secretory.

The yolk or nutritive material within the immature oocytes is denser than the same material in mature oocytes. The yolk of the latter is vacuolated and finely granular. The nutritive material of the mature oocyte becomes separated from the nutritive cord of the apical nurse cells. The yolk of the mature oocyte and the nutritive cord appear to be different in composition and hence stain differently.

The mature oocyte rests within a follicle and upon a peduncle or plug of cells. The latter is composed of oviduct cells which are compressed in a manner similar to the cells at the ends of each follicle. When the oocyte is ripe, it ruptures the epithelial plug of the follicle and passes into the oviduct (Plate VI, figs. 23, 26).

The epithelium of both the lateral and the median oviducts is similar. The cells are low-columnar to cuboidal in shape and rest on a thin basement membrane. The nuclei of these cells are round, centrally placed and granular. The cytoplasm of these cells is granular also. The cells appear to be active glandular cells. The lumen of the oviduct contains a reticulate arrangement of material. The writer assumes this to be the abundant secretion of the oviduct cells, formed into a net by fixative reagents.

Outside the basement membrane of the oviduct cells are the muscular elements of the oviduct wall. The longitudinal muscles are tight against the basement membrane. The circular muscles are outside the longitudinal muscles. Surrounding the oviducts is the peritoneal sheath. The latter is thin and composed of two thin membranes with scattered, elliptical nuclei.

Riley (1907) states that the cells of the peritoneal sheath, the terminal filament, and the epithelium of the germarium and follicles are of a common origin, but that these somatic cells differ in origin from the sex and nutritive cells.

Kohler (1907) states that cell division occurs by mitosis in the peritoneal epithelium and terminal filament and germarium in the egg tube and that amitotic division occurs in follicular epithelium. The latter is confined to the nuclei and never leads to cell division.

EXPLANATION OF PLATE VIII

FIG. 31. Dorsal view of the nervous system.

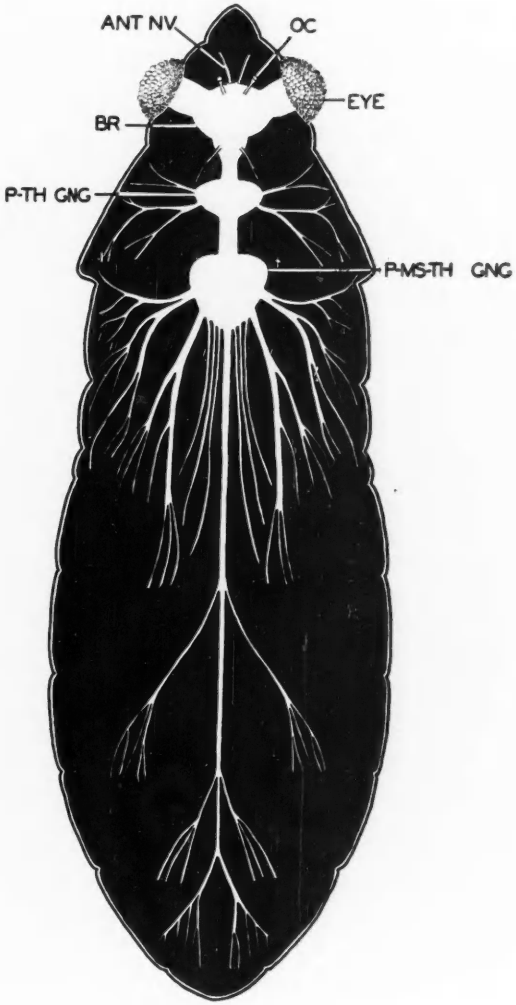

FIG 31

THE MALE REPRODUCTIVE SYSTEM

The testes of male Hemiptera have six follicles in a single scrotum according to Essig (1942). However, *Leptocoris* has seven follicles in a single scrotum. Baumgartner and Witherspoon (1937) mention the same number of follicles for *Anasa tristis*, a member of the same family, the Coreidae.

The seven follicles or sperm tubes of the box elder bug testes are compacted. The testes are yellow-orange in color and are wedge-shaped. Each follicle of the testis is invested by a peritoneal sheath and the entire testis is inclosed in a similar covering. Like the ovaries of the female box elder bug, each testis is suspended from the dorsal wall of the prothorax by a single suspensory ligament.

The posterior end of each testis attaches to its vas deferens. Each of the two vasa deferentia is dilated midway between the testis and the ductus ejaculatorius (Plate VII, figs. 28, 30). These expansions, which function as a pair of small seminal vesicles, appear as elongate swellings noticeably on the lateral surfaces of the vasa deferentia.

At the junction of the two vasa deferentia and on the dorsal surface of the same, there is a large pyriform organ (Plate VII, figs. 27, 30). The writer assumes the latter to be fused accessory glands since others were not found. Male insects in general have two such glands.

Both the seminal vesicles and the accessory gland are translucent structures. The latter is continuous with the ductus ejaculatorius (Plate VII, fig. 30).

THE HISTOLOGY OF THE MALE REPRODUCTIVE SYSTEMS

The testes are made up of a series of tubular follicles. The latter are bound together in one plane by a sheath of peritoneum. This grouping of the follicles determines the general shape of the testis.

A follicle consists of a layer of epithelial cells, which lies on a thin basement membrane. The edges of the epithelium join and make a conducting cylinder. A peritoneal membrane invests the follicle and is continuous with the covering of the testis. The follicles of *Leptocoris* are expanded apically and taper to a narrow end at their basal ends: Each follicle in the testis opens separately into the vas deferens.

Snodgrass (1935) differentiates the testicular follicles of insects into four zones in which the sex cells are in different stages of development: first, the germarium, the zone of the spermatogonia; second, the zone of spermatocytes in which cysts of spermatocytes are formed from the spermatogonia; third, the zone of maturation and reduction, in which the spermatids are formed; and fourth, the zone of transformation, in which the mature spermatozoa develop from spermatids.

The above zones are not clearly differentiated in *Leptocoris*. Examples of the different characteristics of some zones are clearly recognizeable, however, and some of these will be pointed out later.[3]

The apex of each follicle contains rounded, dark staining cells with large nuclei. These cells are generally grouped together and are

[3]For details regarding the process of spermatogenesis in the coreid *Anasa tristis*, the writer would refer to Baumgartner and Witherspoon (1937), who cite Foot and Strobel (1907) and Paulmier (1899), both of whom describe parts of the same process.

surrounded by a thin membrane. The cells posterior to the apical spermatogonia resemble the latter quite markedly. The writer had difficulty distinguishing between the cells within the follicles other than the spermatids and spermatozoa.

In longitudinal section the early stage spermatids are cuneiform in shape. They are found in the peripheral margins of their enclosing cysts. In a later stage the cytoplasm of the spermatids has decreased, the pointed end of the cell has increased in length and the nucleus has become darker. The pointed portion continues to elongate and the cytoplasm all but disappears around the elongated nucleus.

The resulting spermatozoa have long tails and rod-shaped heads. The sperm cells are packed in bundles in the basal ends of the follicles anterior to the vasa deferentia (Plate VII, fig. 29).

The cuboidal epithelial cells of the basal ends of the follicles resemble the cells of the vas deferens. Each of these epithelia rests on a basement membrane. The nuclei of the cells are oval and the cytoplasm is granular.

The seminal vesicles in the male box elder bug appear to be lateral outpouchings of the vas deferens. The epithelium of both the vas deferens and the seminal vesicle is cuboidal although the cells in the seminal vesicle epithelium are smaller and tend toward columnar shapes.

The seminal vesicle has an abundant muscular layer. The latter is noticeably lacking in the vas deferens. Both circular and longitudinal muscles are present in the wall of the seminal vesicle. There are also scattered cells between the epithelial layers which seem to be connective tissue cells (Plate VII, fig. 28).

A large group of glandular cells is found at the junction of the two vasa deferentia (Plate VII, figs. 27, 30). The writer assumes this mass to be the fused accessory glands. The cells are oval and their nuclei and cytoplasm stain very darkly. The cytoplasm is granular. There is some evidence of secretion in the lumen of the gland at its junction with the ductus ejaculatorius.

The cells of the ductus ejaculatorius are cuboidal and resemble the epithelial elements of the vas deferens.

The testes, vasa deferentia, seminal vesicles and ductus ejaculatorius are enclosed in a thin, peritoneal sheath. The latter membrane is double and has scattered nuclei.

THE NERVOUS SYSTEM

The nervous system of insects generally "consists of a mass of nerve tissue, the ***brain***, lying above the anterior end of the stomodaeum, and of a ***ventral nerve cord***, composed of median segmental ganglia and paired connectives, lying beneath the alimentary canal." (Snodgrass, 1935).

There are some insects, however, in which the structure of the nervous system has become modified. Especially is the latter true of the ventral nerve cord. The ganglia of the latter may be fewer in number or they may be fused. The connectives and commissures may be different or may have disappeared. In some of these cases there is a definite "cephalization" of the nervous elements (Negi, 1934; Nel, 1933; Hamilton, 1931). The ganglia are fused anteriorly into larger masses and the connecting nerve trunks or commissures are absent. The

writer believes the nervous system of the box elder bug to be an outstanding example of this "cephalization" in insects with respect to the nervous system. The bug has a peculiar and picturesque arrangement of ganglia and nerve trunks (Plate VIII).

The nervous system of *Leptocoris* is concentrated in the head and thorax (Plate VIII, fig. 31). It consists of a supraoesophageal ganglion, which occupies the posterior two-thirds of the cranial cavity; a fused suboesophageal ganglion; a transverse, oval ganglion in the anterior portion of the prothoracic cavity, which is connected to the suboesophageal ganglion by two large connectives; and a large, heart-shaped ganglion (referred to as "central ganglion" by Hamilton, 1931 and "pterothoracic ganglion" by Malouf, 1933) which lies in the prothoracic and mesothoracic cavities and is connected to the oval ganglion in the prothoracic cavity by two broad connectives. The heart-shaped ganglion represents the fused elements of most of the ventral nerve chain; it comprises the ganglia of the mesothorax, metathorax, and abdomen.

Two pairs of large nerves extend from the lateral edges of the large, heart-shaped ganglionic mass. Three pairs of smaller nerves extend from its posterior margins. The ganglion terminates in one large nerve trunk which extends caudad along the median line from the posterior edge of the ganglion. There are three pairs of branching nerves which arise from the latter nerve trunk and extend to organs in the abdomen.

The supraoesophageal ganglion occupies the epicranial portion of the head. The main portion consists of two rounded lobes from which stubby, cylindrical optic lobes arise and extend to the eyes. The ocellar pedicels arise from the dorso-anterior regions of this ganglion, one from each bulb of the protocerebrum. A pair of antennal nerves arises from the ventroanterior portion of the supraoesophageal ganglion and extends to the antennae.

The suboesophageal ganglion is directly beneath the supraoesophageal ganglion and is connected to the latter by short circumoesophageal commissures. The compact arrangement of the brain and suboesophageal ganglion leaves little space around the oesophagus and the anterior aorta. This cephalic mass of nerve tissue closely invests the latter organs, so much so that the circumoesophageal commissures are indistinct, and the elements of the latter are lost in the fusion of the brain and the suboesophageal ganglion.

From the anterior portion of the suboesophageal ganglion a pair of nerves arise which innervate the proboscis. Another pair of nerves arise from the dorsoposterior edge of the same ganglion and extend caudolaterally into the neck region.

Two connectives extend posteriorly from the suboesophageal ganglion and connect with the prothoracic ganglion. This oval ganglion lies in the prothoracic cavity. The width of the ganglion is greater than its length and extends transversely. Two nerve trunks arise from the ganglion and extend laterad. The most anterior of these extends to the legs. The posterior trunk innervates the thoracic muscles.

Two cylindrical connectives arise from the posterior margin of the prothoracic ganglion and extend caudad. They join the large, heart-shaped ganglionic mass.

The heart-shaped ganglion ("central ganglion" or "pterothoracic ganglion") is unique. It is the last in the ventral chain and evidently comprises the ganglia of the abdomen and of the last two thoracic segments. From its lateral edges a pair of large nerve trunks arises, bifurcates and extends laterad. These bifurcations branch again and the lateral extensions thus formed innervate the legs and wings.

There is a pair of nerve trunks which arises posterior to the above mentioned pair of nerve trunks. This second pair of large nerve trunks arises on the posterolateral margins of the ganglion and extends caudolaterad. The trunks bifurcate and the branches innervate regions of the alimentary canal.

In addition to the two large nerve trunks there are three pairs of small nerves which project caudad from the posterior edges of the ganglion. They innervate viscera and muscles.

The ganglionic mass in the prothoracic and mesothoracic cavities terminates in a median nerve trunk. The latter extends down the median line in the abdomen. Three paired main nerve branches arise from this long median nerve trunk. The first pair arises in the third abdominal segment and innervates the viscera in the same region of the abdomen. The second pair of nerves arises in the fifth abdominal segment and innervates the gonads. The median nerve trunk then branches dicotomously and innervates the viscera, sex organs and muscles of the posterior abdomen.

The histological structure of the ganglia consists of an outer coat of ganglionic cells. The nuclei of these cells are varied in size and stain darkly. The inner, whitish-grey, medullary region is composed of an interlacing network of nerve fibers. The nerve trunks and nerves have a similar composition, a lightly-staining fiber mass and a thin cellular covering with a few scattered nuclei.

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COLEOPTERA OR BEETLES EAST OF THE GREAT PLAINS, by J. Gordon Edwards. Edwards Brothers, Inc., Ann Arbor, Mich. 181 pages. 1949. Price, $3.50.

This is a book which everyone interested in beetles will find of considerable value. It contains quite a bit of general information on beetles, a key to the families occurring in the eastern part of the United States, a discussion of each family, and a very complete list of references.

The introductory pages (pp. 1–9) contain information on such subjects as the literature on the Coleoptera, nomenclature and beetle relationships, structural characters of beetles, the use of the key, and a list of the families of beetles (with the number of species and varieties in each family in the United States as well as east of the Mississippi River). The key to families, which covers 42 pages, utilizes a number of characters not used in other beetle keys, and should be easier to use than many of the older keys, particularly for the student. The key is illustrated with 449 original drawings on 23 plates, which are located opposite the pertinent pages of the key. Many of the drawings appear in the plates two or more times, in order that they will be opposite those parts of the key to which they apply. Following the key, each of the 136 families recognized by the author is discussed separately, in alphabetical order. These discussions contain information on the characteristics of the family, means of distinguishing it from similar families, comments on the more important genera and species in the family, often keys to the subdivisions of the family, notes on the life history and characteristics of the larvae, and a list of taxonomic references on the family. These discussions will enable the reader to identify 569 genera and 344 common species. The book concludes with a phylogenetic list of families, a glossary, and an index.

In his delineation of beetle families, the author follows primarily the arrangement in Leng's catalogue; in a few cases, where the adults can be relatively easily separated, he has used other groupings. For example, the Scarabaeidae have been split up, with the Acanthoceridae, Geotrupidae, and Trogidae as separate families; the chrysomelid group is broken up into several families; and the Spondylidae have been separated from the Cerambycidae because the adults can be readily separated from other cerambycids.

This book is prepared primarily for the student, and the discussions are for the most part very clear and concise. There are a few typographical errors and a few misstatements, but they are in most cases minor in nature. This is an outstanding contribution to entomological literature, and one that should prove very useful for years to come.—D. J. Borror.

THE ENTOMOLOGICAL SOCIETY OF AMERICA

PROCEEDINGS OF THE FORTY-THIRD ANNUAL MEETING

New York City, New York, December 13-16, 1948

The Entomological Society of America held its forty-third annual meeting Monday through Thursday, December 13–16, 1948, in conjunction with the annual meeting of the American Association of Economic Entomologists. Headquarters were at the Hotel New Yorker. Attendance for the combined meetings totaled over 600. Several joint sessions were held with the American Association of Economic Entomologists.

The following sessions of the Society were held:

Monday, December 13

8:30 A. M.—Registration.

10:00 A. M.—Joint session. President Knight called the meeting to order and introduced S. A. Rohwer, President of the American Association of Economic Entomologists, who delivered his presidential address.

11:00 A. M.—Explanation of exhibits.

1:30 P. M.—General Session. President Knight called the meeting to order and appointed the following committees:

Nominating Committee: ALFRED E. EMERSON, J. F. YEAGER, and C. F. W. MUESEBECK, Chairman.

Resolutions Committee: MARION E. SMITH, CURTIS W. SABROSKY, and H. B. HUNGERFORD, Chairman.

The meeting continued with presentation of papers.

Tuesday, December 14

9:00 A. M.—Joint Session. This consisted of a symposium on the subject "Toxicity of Insecticides to Plants and Animals Other Than Man." S. A. Rohwer acted as chairman.

1:30 P. M.—Physiology Section. Presentation of papers. Chairman, J. Franklin Yeager.

8:00 P. M.—Annual public address of the Entomological Society of America. Dr. B. V. Travis gave an illustrated lecture on "The Ecology of Alaska."

Wednesday, December 15

9:00 A. M.—Joint Session. This was a panel discussion with invitation papers on the subject "Formulation of Insecticides."

9:00 A. M.—Taxonomy Section. Presentation of papers. Mont A. Cazier, Chairman.

1:30 P. M.—Joint Session with teaching section of American Association of Economic Entomologists. H. O. Deay, Chairman.

1:30 P. M.—Physiology Section. Symposium: The Technology of Physiological Measurements. Robert L. Patton, Chairman.

7:00 P. M.—Entomologists' Banquet. After the banquet, John T. Creighton presented some colored movies on his entomological experiences in Central America.

Thursday, December 16

9:00 A. M.

BUSINESS SESSION

President Knight called the meeting to order and asked for the report of the Secretary.

REPORT OF THE SECRETARY

Executive Committee Activities:

On March 17, President Knight re-appointed DR. P. W. OMAN and DR. S. W. BROMLEY to serve on the Joint Committee on a History of Entomology in relation to the war effort.

DR. P. W. OMAN and the Secretary were appointed to represent the Entomological Society in conference with the Surgeon General at Washington, D. C. The delegates attended a two-day conference at the Pentagon Building.

DR. W. T. M. FORBES and DR. Z. P. METCALF were appointed as official delegates of the Society to the International Zoological Congress in Paris and the International Entomological Congress in Stockholm. DR. ALAN STONE was appointed as delegate from our Society to attend the International Congresses on Tropical Medicine and Malaria.

DR. MAURICE T. JAMES was appointed to the Editorial Board as Managing Editor of the ANNALS.

MR. R. S. FILMER and DR. C. H. CURRAN were appointed as members of the Local Arrangements Committee for the meetings in New York.

The Committee on Insect Physiology submitted the following as members of the Insect Physiology Foundation:

Editor—W. R. HORSFALL.

Editorial Board—LEIGH CHADWICK, December, 1948–December, 1954.
GLENN RICHARDS, December, 1948–December, 1954.
V. G. DETHIER, December, 1948–December, 1952.
J. FRANKLIN YEAGER, December, 1948–December, 1952.
R. L. PATTON, December, 1948–December, 1950.
C. W. KEARNS, December, 1948–December, 1950.

In accordance with this action, the Secretary-Treasurer transmitted to the Editor of the Insect Physiology Foundation the sum of $1,000 from the Permanent Fund of the Society as per instructions from the preceding business meeting. The seven members of the Insect Physiology Foundation were notified of the action and the Foundation was thereby officially founded.

The sum of $250 was authorized for expenditures of the Committee on a History of Entomology with the war effort.

Officers of the Physiology Section were appointed as follows: J. FRANKLIN YEAGER, Chairman; ROBERT L. PATTON, Vice-Chairman; and A. GLENN RICHARDS, Secretary. At the same time the Executive Committee set up a Taxonomy Section with the following officers: MONT CAZIER, Chairman; E. G. LINSLEY, Vice-Chairman; and C. W. SABROSKY, Secretary.

Twenty new members were elected by mail ballot.

Annual Executive Committee Meeting:

This meeting convened on the evening of December 13 with the following members present: H. H. KNIGHT, P. W. OMAN, W. GERTSCH, M. T. JAMES, J. F. YEAGER, H. H. ROSS; and alternates E. O. ESSIG, A. C. HODSON, C. D. MICHENER.

1. Twenty-four new members were elected to the Society.

2. The following members have resigned during the year: C. A. CLARK, R. H. COOPER, J. H. HAWKINS, C. B. HUFFAKER, JOHN W. JOHNSON, K. M. KING, W. H. LARRIMER, H. A. MORGAN, A. W. MORRILL, H. R. PAINTER, W. W. SMITH, CHARLES J. SORENSON, H. D. TATE, W. Y. WATSON, HIRAM C. YOUNG. The following members have been dropped from membership because of failure to pay dues or because they can not be reached: SUNG HIN AU, WILLIAM D. BEDARD, HUGH W. BEDFORD, ERWIN J. EPSTEIN, JOHN A. FLUNO, FLORENCE M. FROST, FREDERICK M. GAIGE, FRED C. HARMSTON, MOHAMMED KAMAL, P. H. MARVIN, M. J. OOSTHUIZEN, EZEKIEL RIVNAY, WILLIAM A. ROSS, M. B. SAILSBURY, ROBERT C. SCHNITZER, A. R. SUMMEROUR, GENEVIEVE WILLIAMS, J. D. WORCHESTER.

3. It was recommended that R. E. SNODGRASS and WILLIAM A. RILEY be elected as Honorary Fellows of the Society.

4. The following were elected as Fellows of the Society: A. N. TISSOT, BERNARD V. TRAVIS, JOHN L. BUYS, EUGENIA MCDANIEL, GEORGE S. TULLOCH.

5. The Society has suffered the loss by death of the following members: J. R. DE LA TORRE BUENO, E. T. CRESSON, JR., A. T. DAMPF, ALFRED FENTON, WILLIAM D. FUNKHOUSER, HUGH GLASGOW, C. L. METCALF, PHIL RAU, C. M. WEED, C. C. WILSON, C. J. WAINWRIGHT. After the reading of the names, the members stood in silence in memory of the departed.

6. The following were elected to fi'l vacancies of the Editorial Board, and to serve until 1951: A. GLENN RICHARDS, STANLEY FREEBORN, WILLIAM C. COOK.

7. E. S. ROSS and C. E. MICKEL were elected to the Thomas Say Foundation to serve until 1950.

8. It was voted to contribute $100 to the support of Zoological Record.

9. It was voted that the Historical Committee as at present constituted be placed on a permanent basis, with reappointments to be made by the Executive Committee as needed.

10. In a discussion of the Joint Committee on the Preparation of a History of Entomology in Relation to World War II, it was agreed that the appointment of the committee and the allocation of funds be for the duration of the project.

11. The meeting place for the 1949 meeting was set for Tampa, Florida, December 13–16, in co-operation with the American Association of Economic Entomologists.

12. It was moved that the President be authorized to appoint a Program Committee to assist in planning the annual meetings, if this seems desirable.

13. It was moved that a permanent Taxonomy Section be set up on a parallel basis with the Physiology Section, with the same number of officers, to be appointed annually by the Executive Committee.

14. The following were appointed as officers of the Physiology Section: Chairman, A. GLENN RICHARDS, JR.; Vice-Chairman, LEIGH CHADWICK; Secretary, R. L. PATTON.

15. The following were appointed as officers for the Insect Taxonomy Section: Chairman, C. E. MICKEL; Vice-Chairman, A. N. TISSOT, Secretary, CURTIS SABROSKY.

Respectfully submitted,

HERBERT H. ROSS, *Secretary.*

On motion, the Secretary's Report was adopted as read.

The recommendation for Honorary Fellows was put forward as a motion and a ballot taken. Both members received unanimous approval and were elected.

TREASURER'S REPORT

DECEMBER 23, 1947, TO DECEMBER 3, 1948

CURRENT FUND

Balance on hand December 23, 1947	$1,751.58
Receipts	7,547.66
Total	$9,299.24

EXPENDITURES

Annals (3 numbers)	$4,214.46
Expenses of Secretary-Treasurer's office, including cost of Chicago meetings	399.29
Travel expenses and registration fees of delegates	58.71
Checks returned, bank charges, and refunds	27.80
To Zoological Society of London	100.05
To Committee on History of Entomology	21.29
Total	$4,821.60
Balance in bank, December 3, 1948	4,477.64
Total	$9,299.24

PERMANENT FUND

Balance on hand December 23, 1947	$4,612.67
Interest	10.00
Liberty bond and coupons due	52.87
Total	$4,675.54
Withdrawal for Insect Physiology Foundation	1,000.00
Balance	$3,675.54

TOTAL RESOURCES OF SOCIETY

Balance in Current Fund	$4,477.64
Balance in Permanent Fund	3,675.54
Total	$8,153.18

Respectfully submitted,

HERBERT H. ROSS, *Treasurer.*

The Treasurer's Report was adopted subject to approval by the Auditing Committee.

REPORT OF THE MANAGING EDITOR

Because of conditions beyond the control of either my predecessor, Dr. Lindsey, or myself, publication of the numbers of the ANNALS for 1948 has been delayed. The work passed on to me was, of necessity, considerable, and my efforts have been to bring the publication up to date.

We have at present enough accepted manuscripts to publish at least 400 pages. I hope more material than this can be handled during 1949, but I do not want to promise publication for the year in excess of that number. In the future, acceptable manuscripts will be published with exceptions to be noted presently, in the order received. Some deviations from this plan are being made at present, because of our reorganization. For example, some manuscripts have been held up by conditions beyond our control, and it is only fair to the authors to get these into print as soon as possible. Also, in cases in which the author or the institution which he represents pays full cost, publication will be immediate. This does not, however, penalize other authors, since those pages will simply be added to the regular issue.

In New York, I met with the editorial board and agreement was reached on some important matters of policy. We felt that fairness demanded that priority in publication be given to members of the Society, but that we must give consideration, on the one hand, to worthy papers by non-members, and that, on the other, we should have no obligation to accept inferior papers by members. Publication should be sought elsewhere for purely economic papers, most biographical accounts, and for those often quite worthy papers of more local interest. The ANNALS prefers comprehensive descriptive works or those based on experimental research dealing with the more fundamental aspects of insect biology. Unfortunately, our acceptance of long papers is very limited, and the author or his institution will, in the future, have to be asked to pay part of the publication costs for such. It may at times be desirable to set very short papers ahead of

schedule in order to balance the subject matters or to round out the desired number of pages for an issue.

My acceptance of the position of Managing Editor of the ANNALS was made possible by the co-operative attitude and actual encouragement of the State College of Washington. President Wilson Compton, Dean C. C. Todd, and the other administrators not only expressed their approval, but offered material help in the way of supplying me with the necessary stenographic help. I wish also to express my appreciation to my colleagues, especially to Dr. Horace S. Telford and Dr. Morris Rockstein, for material aid during this reorganization period.

The following financial report will close Dr. Lindsey's books. The relatively small amount of material for the remainder of 1948 will be included in next year's report.

FINANCIAL STATEMENT

DECEMBER 10, 1947, TO NOVEMBER 1, 1948

RECEIPTS

Non-member sales and subscriptions	$ 120.22
From the Columbus office, subscriptions	1,358.00
Gorgas Memorial Foundation, printing	139.79
From authors for cuts	485.51
Bank balance, December 10, 1947	3,044.66
Total	$5,148.18

DISBURSEMENTS

Engraving	$ 272.19
Postage	86.07
Stationery, wrappers, and miscellaneous service and supplies	49.97
Refunds on subscriptions	9.45
Stenographic and addressograph service	291.50
Transferred to Treasurer	3,500.00
Bank charges	2.06
Transferred to M. T. James	936.94
Total	$5,148.18

Respectfully submitted,
MAURICE T. JAMES, *Managing Editor.*

The Report of the Managing Editor was adopted subject to approval by the Auditing Committee.

REPORT OF THE TREASURER OF THE THOMAS SAY FOUNDATION

RECEIPTS

Balance on hand December 23, 1947	$3,764.86	
1947 sales paid in 1948	32.10	
1948 sales of 22 volumes of 1, 2, and 3	88.89	
1948 sales of 183 volumes of 4	1,120.35	
Interest on deposits	21.42	
Total Receipts		$5,027.62

EXPENDITURES

Publication of volume 4	$3,293.05	
Express charges on books	117.34	
Express on mailing cartons	1.10	
Postage on books	28.84	
Postage on correspondence	7.00	
Total Expenditures		$3,447.33
Balance		$1,580.29
Balance in Purdue State Bank		$1,584.54

Respectfully submitted,
J. J. DAVIS, *Treasurer.*

Report adopted subject to approval of the Auditing Committee.

REPORT OF THE AUDITING COMMITTEE

We, the undersigned members of the Auditing Committee, beg to report that we have examined the accounts for the year 1948 of H. H. Ross, Treasurer of the Society, and have found them to be correct and properly balanced. Accounts of the Managing Editor of the Annals were not examined because they were in process of transfer to the new editor. Accounts of J. J. Davis, Treasurer of the Thomas Say Foundation, were not complete at the time the audit was made.

Respectfully submitted,
B. E. Montgomery,
A. M. Dewey,
William R. Horsfall, *Chairman.*

REPORT OF THE INSECT PHYSIOLOGY FOUNDATION

The Insect Physiology Foundation was organized according to the recommendation approved at the business meeting of the Society in December, 1947. The function of this foundation is to publish the Journal of Insect Physiology.

The Foundation has received a starting fund of $1,000 appropriated by the Society. Funds for publication of Volume 1 will be sought before printing begins.

The Editorial Board met in New York in December and approved plans for raising funds for the Journal.

Respectfully submitted,
William R. Horsfall, *Editor.*

On motion, this report was adopted as read.

Dr. F. Butt gave a very entertaining report on the International Entomological Congress at Sweden and announced that the next International Congress will be in Amsterdam, Holland.

REPORT OF THE JOINT COMMITTEE ON THE PREPARATION OF A HISTORY OF ENTOMOLOGY IN RELATION TO WORLD WAR II

The American Association of Economic Entomologists and the Entomological Society of America authorized the expenditure of not to exceed $1,000.00 ($750.00 from the A.A.E.E. and $250.00 from the E.S.A.) for the services of the editor and other necessary expenditures in connection with the writing of the History. Following the allocation of these funds, the Committee completed arrangements with Col. E. C. Cushing who was selected as General Editor.

Although much work remains to be done in connection with the reviewing and abstracting of accumulated information, considerable progress has been made in this connection and the actual writing of the History has been under way since approximately mid-year of 1948. It is anticipated that the History will be in final form by the time of the 1949 Annual Meetings of the sponsoring Societies.

Stanley W. Bromley,
Ralph W. Bunn,
Edward F. Knipling, *Co-Chairman.*
P. W. Oman, *Chairman.*

This report was read by Dr. Oman who moved its adoption. Motion carried.

ANNUAL REPORT OF AMERICAN COMMITTEE ON ENTOMOLOGICAL NOMENCLATURE

The outstanding nomenclatural event in 1948 was the meeting of International Commission on Zoological Nomenclature in connection with the Thirteenth International Congress of Zoology in Paris. Notice of some of the most important decisions taken at this meeting has been published in *Science* and elsewhere. In anticipation of this meeting of the Commission, the American Committee on Entomological Nomenclature studied some of the pending cases for which the Commission had published advance notice of applications. The results of this study were communicated to the Commission. In addition, the Committee prepared two applications of its own and submitted them to the Commission. The first of these involved the status of names given to forms of less than subspecific rank. The second petition related to generic names published after December 31, 1930, without definite unambiguous designation of the type species.

Following the Paris meeting, the Secretary of the International Commission notified the Committee that these matters were considered by the Commission and decisions reached on the various phases of these two problems which had been included in the petitions.

Members were elected or re-elected for 3-year terms to fill vacancies in the Committee as follows: M. A. CAZIER, C. W. SABROSKY, E. G. LINSLEY.

Officers elected for the year 1949 are E. G. LINSLEY, Chairman, and C. D. MICHENER, Secretary.

Respectfully submitted,

E. G. LINSLEY, *Secretary.*

DR. LINSLEY was unable to be present so the report was read by DR. C. W. SABROSKY. The report was adopted as read.

DR. OMAN gave an oral report on the conference attended by himself and the Secretary at the Surgeon General's office. DR. STONE then gave an oral report on the International Congress on Tropical Medicine and Malaria, held in Washington, D. C., and sponsored by the State Department.

It was moved and seconded that the question of abstracts for programs be considered for the next meeting. The question of the financial outlay for this was brought up and the motion passed with the understanding that it was to be construed as a recommendation if the proposition proved feasible.

It was moved and seconded that a membership committee of five members be named to lead a campaign to increase our membership. Motion carried.

REPORT OF THE RESOLUTIONS COMMITTEE

1. *Resolved*, that the Society express its appreciation to the Joint Committee for local arrangements: CHARLES L. SMITH, *Chairman;* GEORGE C. BECKER, C. H. CURRAN, HENRY HAYNES, R. S. FILMER; and to the officers of the Society, for their efforts on behalf of this meeting.

2. *Resolved*, that the Society express its gratitude to the management of the Hotel New Yorker for its exceptionally fine spirit of co-operation in making this a successful and enjoyable meeting.

3. *Resolved*, that the Society extend its appreciation to DR. B. V. TRAVIS for his interesting presentation of the Annual Public Address on "The Ecology of Alaska."

4. *Resolved*, that the Society express its sincere regret for the loss through death of several of its members during the past year and that an expression of sympathy be sent to the families of the deceased.

5. *Resolved*, that the Society commend the establishment of the Taxonomy Section and trust that it will continue to be an important feature of the annual meeting.

6. *Resolved*, that the Society express its gratitude to the retiring editor, A. W. LINDSEY, for his years of service to the Society in the editorial work on the ANNALS.

7. *Resolved*, that a letter of appreciation be sent to the State College of Washington and the University of Illinois expressing the appreciation of the Society for clerical help which has been made available for Society officers.

Signed: MARION E. SMITH,
CURTIS W. SABROSKY,
H. B. HUNGERFORD, *Chairman.*

REPORT OF THE NOMINATING COMMITTEE

The Nominating Committee unanimously nominates:

For *President*.....ALVAH PETERSON
First Vice-President.....A. GLENN RICHARDS
Second Vice-President.....PAUL O. RITCHER
Secretary-Treasurer.....H. H. ROSS
As members of the *Executive Committee*.....E. G. LINSLEY, O. E. TAUBER
Councilors to the American Association for the Advancement of Science:
ALFRED E. EMERSON, 2-year term; J. F. YEAGER, 1-year term

C. F. W. MUESEBECK, *Chairman.*

It was moved that the Secretary be instructed to cast a unanimous ballot for these officers. Motion carried.

The meeting then adjourned.

REPORT OF REPRESENTATIVE TO NATIONAL RESEARCH COUNCIL

The Division of Biology and Agriculture, National Research Council, held its annual meeting Thursday, May 5, 1949, at the Academy Building in Washington, with Chairman RALPH E. CLELAND presiding. Minutes of the last meeting were approved. DR. D. W. BRONK spoke extemporaneously of the purpose and activities of the Council. Secretary MILTON O. LEE reported that the Agriculture Board had been reconstituted and was due to hold a meeting on May 9. One of its important activities was to be a study of the effect of sanitary regulations on milk quality. The Food and Nutrition Board was due to meet on May 7. The American Institute of Biological Sciences had met on May 5. The Institute had been founded just a year ago with the purpose of advancing biological sciences and their applications to human welfare.

The Institute, it was reported, has under way a project on a handbook of biological data. The first section of the handbook has been contracted for and will be completed in the next few months. This fascicle will deal with blood. Following its completion a decision will be made with regard to the underwriting of the remainder of the projected handbook.

Another project of the Institute of great importance, *viz.*, the work of the Committee on Selective Service, was reported on by DR. L. W. PARR. It was stated that as a result of the labors of this committee and with the complete cooperation of General Hershey's Committee, it now appears definite that biology in its broader aspects will be recognized in the future in any over-all screening program designed to make most effective use of scientific and specialized personnel in time of national emergency. Seventeen biological societies now carry full membership in the Institute and two others have affiliated. These include no entomological societies [which in the opinion of the representative is very unfortunate, H.M.H.]. Information on the A.I.B.S. is available from the National Research Council. There were reports or discussions from various committees of the Division—the Committee on Aero Biology, American Type Culture Collections, Committee on Fellowships, Committee on Advisory Service to the Armed Forces, the Pacific Science Board, Committee on Investigation of Waste Disposal, etc. DR. S. J. DU PLESSIS, University of Stellenbosch, Union of South Africa, addressed the Division on plant research development in South Africa; DR. HARRY KELLEY on problems in Japan; and DR. HAROLD J. COOLIDGE on activities of the Pacific Science Board. The latter report dealt in part with problems with attempts at biological control of the giant African snail and the rhinocerous beetle of cocoanuts and certain other pests in the Hawaiian Islands.

The Board membership was then constituted into committees, with additional representatives indicated, to review applications for support for foreign travel and study. Two applications came before the Committee on Entomology. The Fullbright Act was discussed by DR. TRYTTEN and the work of the Chemical and Biological Control Division by DR. KERNER. The objectives of the latter include cataloging information from the literature, serving as a screening center, and preparation of reviews that relate structural relationships of chemicals to biological qualities. Its work should be of immense importance to entomology.

Respectfully submitted,

May 16, 1949. H. M. HARRIS.

OBITUARIES

THEODORE DRU ALISON COCKERELL, scientist and humanitarian, an honorary fellow of the Society, died in San Diego, California, on January 26, 1948. Though in spite of frail health he had lived a long and extremely fruitful life, he was active to the last.

It is fortunate that Professor Cockerell left us what might serve as an autobiography. I had urged him to prepare such a document, and no doubt others had done so also, as he published in Bios[1] a series of fourteen articles entitled "Recollections of a Naturalist." These articles, in addition to giving some of the details of his life, have portrayed in his own words the more essential phases of his philosophy of life and of science.

Theodore Dru Alison Cockerell was born in Norwood, England, August 22, 1866. His second name was given for Henry Dru Drury, a close friend of the Cockerell family and a descendant of the famous entomologist, Dru Drury. In speaking of his childhood Professor Cockerell relates how his father used to bring home all illustrated natural history works he could find, and how eagerly these were read and reread by the young boy. He was a frail child; he has said that he remembered hearing someone say "You must be good to Theo; he will never grow up." His rich background developed in him a very keen interest in natural history. In his youth, he was forced to go to a drier climate for his health, and he spent three years, from 1887 to 1890, in the Wet Mountain Valley of southern Colorado. Apparently cured, he returned to England, where he worked for about a year in the British Museum. During this period the young naturalist developed a close friendship with Alfred Russel Wallace, with whom he had corresponded in Colorado. Probably through the influence of Wallace he was appointed curator of the Public Museum at Kingston, Jamaica, where he assumed duties in June, 1891. The chance to work in the tropics delighted him, and it was there that he began the study of the Coccidae. His health, however, would not permit him to stay. On the invitation of C. H. Tyler Townsend, then professor of entomology at the New Mexico Agricultural College, an exchange of positions was effected. This was, in the long run, fortunate, since it made a teacher of him.

Professor Cockerell has, since that time, remained in the western United States, except for numerous visits and scientific expeditions to various parts of the world. He remained in New Mexico until 1903, and was retained as consulting entomologist for the Agricultural Experiment Station until 1909. From 1900 to 1903 he taught at the New Mexico Highlands University. Then, after a year at Colorado College, as curator of the museum, he began his association with the University of Colorado; this association continued in an active way until his retirement, thirty years later, after which he served in an advisory capacity and was allowed to maintain his office in its previous location. Boulder continued to be his home, though winters were spent, for the most part, elsewhere.

To many men, retirement means more or less the cessation of activity; to Professor Cockerell, it meant the beginning of renewed efforts in scientific investigation. During his years of active teaching, the University had protected his time, so as not to overburden him with teaching duties to the detriment of his research. In 1931, he had joined an expedition, sponsored by the British Museum, into Africa; and now he had time to devote more attention to the bees which had been collected on that expedition. The fauna of the Channel Islands of California also interested him. During the years of World War II, he spent the winters in Palm Springs, California, where he and Mrs. Cockerell were in charge of the Desert Museum. At this time close work was becoming too strenuous for his diminishing eyesight, so in 1943 he had a large part of his collection of exotic bees packed and shipped to the United States National Museum, most of his Nearctic material remaining at the University of Colorado. Nevertheless, he and Mrs. Cockerell spent the winter of 1946–7 at the Escuela Agricola Panamericana in Honduras where they made a large collection of insects, including more than 200 species of bees. Returning to Boulder, he began to work over these bees, many of which

[1]Vol. 6, pp. 372–385, 1935; vol. 7, pp. 149–155, 205–211, 1936; vol. 8, pp. 12–18, 51–56, 122–127, 193–200, 1937; vol. 9, pp. 21–25, 66–70, 117–124, 1938; vol. 10, pp. 35–41, 99–106, 1939; vol. 11, pp. 33–38, 73–79, 1940.

were new to science. This work once interrupted by illness in Boulder, was resumed in California.

Professor Cockerell's work as a scientist is well known. He was an authority of world-wide reputation on the wild bees. Few specialists have as thorough a grasp of their chosen fields as he did. He also had a wide reputation for his work on fossil insects, scale insects and mealy bugs, and the scales of fishes. He had worked on molluscs, plants, and in fact, all groups of animals, from the Protozoa to the mammals. He has said that the ideal education is a "broad one, sharpened to a fine point." His work, in co-operation with Mrs. Cockerell, on the red sunflower, was a contribution to the science of genetics, and his writings contain many contributions to our knowledge of variation in plants and animals, zoogeography, and evolution. He published two books: "Zoology, a textbook for colleges and universities" (1920) and "Zoology of Colorado" (1927); in addition, he is the author of more than three thousand original articles, book reviews, biographies, and other contributions to his science. He was undoubtedly one of the most prolific scientific writers of our time.

Professor Cockerell was not only a great scientist; he was also a humanitarian, a poet, and a philosopher. As a youth he knew William Morris, the British Socialist leader, and this association considerably influenced his political thinking. In later life, in reply to the question as to whether his views on the subject had changed, he said that he still upheld Morris' idea of the brotherhood of man and of co-operation as the foundation of all progress toward better times, but with the recognition of the impossibility or undesirability of bringing about a sudden change in the organization of society. This philosophy of life was well put into practice. He was constantly giving material aid, as well as inspiration, to many deserving students at the University of Colorado, the Latin American countries he visited, and elsewhere. He campaigned zealously for world peace and for the brotherhood of science. He and Mrs. Cockerell lived simply, with few luxuries; but they gave generously, both in personal aid and financial support, to any cause they considered worthy.

Professor Cockerell published one small volume of verse, and some of his poems were published separately or quoted in his other writings. He did not, however, find poetry as satisfactory a medium of expression as prose. His prose, whether written for the specialist in bees or for the general public, was clear, simple, and precise. He was an eloquent speaker in the sense that he spoke easily, in a plain, straightforward manner, with few embellishments, much anecdotal material, and a humor that had to be heard to be appreciated. He often illustrated talks with blackboard sketches; a few easily made chalk marks would produce a figure of quite characteristic appearance, which was easily recognized for what it was intended to be. His sense of humor showed up very characteristically in these sketches. For example, he would not draw one ant, but, rather, two or more, in single file, because, he would explain, "you never see one ant alone." The big decision of his youth was whether to become an artist or a scientist. It is interesting to speculate what Science's loss might have meant for Art.

Poor health prevented Professor Cockerell from completing his university work, as a medical student, in England. His only degrees were an honorary Doctor of Science from Colorado College, and a similar degree from the University of Denver. His work under such men as Wallace and Morris, together with the rigid course of self-training which he prescribed, certainly must have compensated many times for the lack of formal training. He preferred to be called "professor" rather than "doctor."

Some criticism has been directed against Professor Cockerell's work, particularly that so much of it is in small pieces, with little work of a monographic nature. His habit of publishing many small articles may have been due partly to the difficulty of getting long papers published, partly to the uncertainty of the duration of his life. He did produce some works of monographic nature, however, and he has left an enormous amount of material from which subsequent workers may build monographs. He certainly did not, as too many have done, carry a large part of his life's accomplishments to the grave. He worked for science and for the future generations of scientists, in whom he had great faith. One of my treasures is a copy of Essig's "History of Entomology," given to my wife and me by Professor Cockerell, and inscribed in his handwriting with the following (previously published) poem:

TO THE YOUNGER GENERATION

"You will see, where we are blind,
We may seek, but you will find,
Yet as you hold the golden thread
Passed on from days of long ago,
The names of those remembered
For what they strove to do and know
May still have power to stir the mind,
And, passing, leave a gift behind!"

Professor Cockerell is survived by his wife, Wilmatte Porter Cockerell, whom he married during his New Mexico years, and who has been his companion not only in his home but in all his activities. With her visual education program, particularly through the use of teaching moving pictures, she has carried his instruction and research beyond the walls of the University class room.

—M. T. J.

SOL FELTY LIGHT was born in Elm Mills, Kansas, May 5, 1886. His father was a Presbyterian minister, and his maternal grandfather, J. W. McDill, was United States Senator from Iowa, a member of the U. S. Interstate Commerce Commission and U. S. District Judge. Thus his whole life was motivated by great ability, high ideals, strict honesty, and real responsibility that helped to make him the great teacher and investigator that he was. Little information is available concerning his boyhood. His career began at his graduation with an A.B. from Park College, Parkville, Missouri, in 1908. Following graduation he taught English in the Government Schools in the Philippines from 1908 to 1909; was a teacher in the Manila High School, 1910–1911; and joined the staff of the University of the Philippines as an instructor in 1912. During 1912, also, he made an expedition to Puerto Galero, Island of Mindoro, to study the fauna there. He obtained his M.S. at the University of the Philippines in 1913. During the year 1914–1915 he took a leave of absence to become the Procter fellow in Zoology at Princeton University for which he received another M.S. degree in 1925. Returning to the University of the Philippines he became successively assistant professor (1916–1919), associate professor (1919–1920), professor and chairman of the department of Zoology (1920–1922). He resigned in 1922 to become professor and chairman of the newly founded University of Amoy, China, where he remained until 1924.

In 1920 he accompanied an expedition into the interior of Hainan Island and in 1924 he was a delegate to the Pan-Pacific Food Conservation Conference in Honolulu.

During these years in the Orient he published on zoological subjects including termites. He came to the University of California in 1924 to do graduate work for a Ph.D. and began, under Dr. C. A. Kofoid, to explore the flagellates of termites and to study the termite fauna of western United States. In the spring of 1925 he was appointed associate in zoology at the University of California and later in the same year a University fellow; a lecturer in zoology in the fall of that year; a James M. Geoway Fellow in the spring of 1926; assistant professor of zoology in 1926–27. He received his Ph.D. in 1926. His thesis was on termite flagellates. He was associate professor 1927–1929, and professor of zoology from 1929 until his untimely death by accidental drowning while swimming in Clear Lake, near Clear Lake Lodge, California, June 21, 1947.

On January 1, 1925, he married Mary Nesbit Holdcroft (A.B. Park College) at Redwood City, California. She is at present residing in Alameda, California.

Dr. Light was a remarkable teacher and leader of students as well as an unusually conscientious co-operator. He was always interested in entomology and for many years served as an officer of instruction and advisor of the Division of Entomology and Parasitology. He also served on many of the committees in charge of the qualifying examinations and theses of graduate students in this Division. His thorough understanding and keen interest in research and in teaching problems made him an extremely valuable addition to the entomological program in the College of Agriculture.

He was also interested in many outside activities and during his residence in Berkeley he became an important member, officer, and councilor in the First Congregational Church.

He began publication in 1913 and in all, prepared 70 papers.

In entomology his chief interest was termites, in which group he made notable contributions in the systematics and biology of these remarkable social insects. His discoveries in the parthenogenesis and caste determinations are specially important.

He was a member of the American Association for the Advancement of Science; Entomological Society of America; American Association of Economic Entomologists; Cooper Ornithological Club; Western Society of Naturalists; American Eugenics Society; American Society of Zoologists; American Society of Parasitologists; Society of Experimental Biology and Medicine; La Société Linnéenne de Lyon; China Society of Science and Arts; Royal Asiatic Society (North China Branch); Sigma Xi; Phi Sigma.

Dr. Light's collection of termites was disposed of as follows: A large portion was presented to Dr. A. E. Emerson, University of Chicago, in 1939 and approximately 1,000 specimens, representing many species including paratypes, were presented to the Department of Entomology, California Academy of Sciences, San Francisco, during the same year. He also determined and described species in the collections of the Academy.

The writer is indebted to Dr. Richard M. Eakin, chairman of the Department of Zoology, University of California, and to Miss Frances Weesner, technician in the Department of Zoology for much of the information contained herein.

A complete bibliography of his published works will appear in zoological and other scientific papers.—E. O. Essig.

Rufus Hiram Pettit, B. S., D. Sc., consulting entomologist, Michigan State College, died June 1, 1946. Dr. Pettit was born at Baldwinsville, New York, January 11, 1869. He graduated from Baldwinsville Academy in 1887 and after serving two years as an apprentice in a local machine shop, he entered Cornell University. After one year's college work he served a year as anatomist at Ward's Natural Science Establishment, Rochester, New York, when he returned to the University, where he specialized in entomology, receiving his B.S. in agriculture in 1895.

He was assistant state entomologist of Minnesota 1895–1897 under Dr. Otto Lugger. On January 1, 1897, he was appointed instructor of zoology and assistant in entomology on the Experiment Station, Michigan Agricultural College. Entomology separated from Zoology in 1908 to form a new department with Professor Pettit in charge and acting entomologist on the Experiment Station.

Dr. Pettit was a member of the Lambda Chi Alpha Society, Sigma Xi, and Alpha Zeta; a fellow of the American Association for the Advancement of Science; a charter member of the Entomological Society of America and a fellow since 1939; a life member of the Society Linnéene de Lyon, France; a member of the American Association of Economic Entomology and of the Entomological Society of Washington.

In 1895 Dr. Pettit was married to Jessa A. Treat of Ithaca, New York, who survives him, together with their two daughters, Mrs. M. S. Nelson, of Indianapolis, Indiana, and Mrs. M. J. Reed of East Lansing, Michigan.—E. I. McDaniel.

Rudolf William Glaser, a member of the Entomological Society of America since 1916 and a fellow since 1941, died suddenly from a heart attack on September 4, 1947, at Princeton, New Jersey. Since 1920 Dr. Glaser has been an associate member of the Rockefeller Institute for Medical Research in the Department of Animal and Plant Pathology. His interests included the physiology, pathology, bacteriology, protozoology and mycology of insects and of late years his work dealt with biochemical studies of the virus and the inclusive bodies of silkworm jaundice. During the war years he tested many animals for susceptibility to the malarial parasite, in an effort to find a host suitable for experimentation. His early work dealt with the wilt disease of the gipsy moth and his early papers are on this subject. Later he published on bacterial disease of caterpillars, the

nature of polyhedral bodies found in insects, the cultivation of bacteriocytes in the German roach and on many related subjects. The nematode parasite of the Japanese beetle was discovered in New Jersey while Dr. Glaser and Dr. Henry Fox were investigating the mortality of grubs in 1929. By 1931 Dr. Glaser had succeeded in cultivating the nematode on an artificial medium. This finally led to the establishment of a parasite laboratory by the New Jersey Department of Agriculture, by which Dr. Glaser was employed as consultant for 17 years.

Dr. Glaser was a prolific worker whose later papers appeared in the Biological Bulletin, Journal of Experimental Zoology, Journal of Experimental Medicine, Journal of Parasitology, Journal of Immunology, etc. A partial bibliography of 25 of his titles may be found in Edward A. Steinhaus' recent book on "Insect Microbiology" (1946). He was a careful, well trained investigator whose opinions and work were favorably received and appreciated by microbiologists.

Dr. Glaser received his A. B. degree from the University of Michigan in 1911 and from that year until 1913 he was assistant entomologist at Harvard University, from which he received his Sc. D. in 1914. From 1912 to 1920 he was entomologist of the Bureau of Entomology, United States Department of Agriculture. He was born at Cantonsville, Maryland, in 1888, and interment was in Baltimore. At the time of his death he was a member of the American Society of Parasitologists, the Washington Academy of Sciences, the Cambridge Entomological Club, the Michigan Chapter of Sigma Xi and the American Association for the Advancement of Science.—H. B. Weiss.

Hugh Glasgow was born in Tennessee, Illinois, November 17, 1884, and died at his home in Geneva, New York, on July 17, 1948, after a long illness. He received the A. B. degree from the University of Illinois in 1908 and the Ph. D. degree in 1913. He served as assistant entomologist at the University of Illinois from 1912–13 and instructor in entomology from 1913–14. He joined the staff of New York Experiment Station, Geneva, in 1914 as an assistant in research in entomology, became an associate in research in 1920, chief in research in 1926, and professor of entomology and chief of the Division of Entomology in 1938, which position he held at the time of his death.

He was a fellow of the American Association for the Advancement of Science and a member of the Entomological Society of America, of the American Association of Economic Entomologists, and of Sigma Xi. In 1944 and 1945 he served as vice-president of the American Association of Economic Entomologists and chairman of the Eastern Branch.

Although his fields of study and interests covered all aspects of economic entomology related to the fruits and vegetables grown in New York State, Doctor Glasgow was probably best known to New York farmers for his work with the pea aphid, the cabbage maggot, and the cherry maggot, all major problems of growers and processors of these important crops. His work along these and other lines attracted nation-wide, in fact world-wide, attention. Since assuming the duties of head of the Division of Entomology, much of his time was occupied with administrative details, but he never lost touch with farmers and their personal problems and until the last participated actively in the Division's research program. A tireless and extremely conscientious worker, Doctor Glasgow commanded the respect and confidence of his professional colleagues, and, most of all, of the farmers of the state, to a degree seldom attained by experiment station scientists.

We are keenly aware of a personal loss of a genial and true friend. Perhaps we can best express the universal feeling on the part of everyone who came in contact with him at any time by saying that always he was acclaimed as a "grand person." We are proud to have known him!

NEW MEMBERS

Auerbach, Stanley I., Department of Zoology, Northwestern University, Evanston, Illinois.

Becker, Edward C., 231 Natural Resources Bldg., Urbana, Illinois.

Bellinger, Peter F., 234 Fountain Street, New Haven 15, Connecticut.

Boyle, W. Wayne, Box 4708, University Station, Tucson, Arizona.

BUCK, JOHN B., National Institute of Health, Bethesda, Maryland.
COGHILL, D., P. O. Box 135, Stellenbosch, South Africa.
COTT, H. EDWIN, Division of Entomology, University of California, Davis, California.
COUCH, MAX D., 303 Harker Hall, Department of Entomology, University of Illinois, Urbana, Illinois.
CRYSTAL, MAXWELL M., 1634 Popham Avenue, New York 53, New York.
DARSIE, RICHARD F., JR., Department of Entomology, Cornell University, Ithaca, New York.
DEFOLIART, GENE RAY, 116 Oak Avenue, Ithaca, New York.
EDWARDS, GEORGE A., Department of Biology, Tufts College, Medford 55, Massachusetts.
ELLIS, LESLIE L., JR., 3808 Napoleon Avenue, New Orleans, Louisiana.
FARR, THOMAS H., 353 Hall Street, S. E., Grand Rapids, Michigan.
FIELD, GORDON, Fernald Hall, University of Massachusetts, Amherst, Massachusetts.
FISCHER, ROLAND L., Department of Entomology, Kansas State College, Manhattan, Kansas.
FRENCH, ELLERY W., Department of Entomology, University of Hawaii, Honolulu 10, Hawaii.
FRICK, KENNETH E., Irrigation Experiment Station, Prosser, Washington.
GAINES, J. C., Department of Entomology, Texas A. & M. College, College Station, Texas.
GHANI, M. A., Fernald Hall, University of Massachusetts, Amherst, Massachusetts.
HOFMASTER, RICHARD N., Virginia Truck Experiment Station, Box 2160, Norfolk, Virginia.
HOUSE, HOWARD L., Dominion Parasite Laboratory, Belleville, Ontario, Canada.
HOWELL, D. E., Department of Entomology, Oklahoma A. & M. College, Stillwater, Oklahoma.
HUNT, BURTON P., University of Miami, Department of Zoology, Miami, Florida.
IGLINSKY, WILLIAM, JR., Box 1836, College Station, Texas.
INADA, CONSTANCE S., Department of Entomology, University of Hawaii, Honolulu, Hawaii.
KEISTER, MARGARET L., National Institute of Health, Bethesda, Maryland.
LATHAM, ROY, Orient, Long Island, New York.
MCKINNEY, ROBERT W., 145 Hall of Fame Terrace, Apt. 38, Bronx 53, New York, New York.
MAEHLER, K. L., Staff Quarantine Officer, Box 22, Comm. Mar., FPO, San Francisco, California.
MITCHELL, WALLACE C., 213 South Hazel Avenue, Ames, Iowa.
MOWRY, PAUL, P. O. Box 101, Gresham, Oregon.
NEWKIRK, MAURICE, Ashland College, Ashland, Ohio.
OITICICA, JOSE, FILHO, Division of Insects, U.S. National Museum, Washington 25, D. C.
OWENS, VIRGIL H., 107 Whitten Hall, University of Missouri, Columbia, Missouri.
PELA, ALBERT S., Box 3009, College Station, Texas.
QUISENBERRY, BENSON F., Department of Entomology, Oklahoma A. & M. College, Stillwater, Oklahoma.
ROEDER, KENNETH D., Department of Biology, Tufts College, Medford 55, Massachusetts.
SCOTT, HARRY E., Department of Entomology, Ontario Agricultural College, Guelph, Ontario, Canada.
SOLIMAN, ABDEL-AZIZ ABDEL-HAFEZ, Department of Entomology, University of Minnesota, St. Paul, Minnesota.
STEYSKAL, GEORGE C., 27253 West River Road, Grosse Ile, Michigan.
STROUD, CLYDE P., P. O. Box 1103, Santa Fe, New Mexico.
VINCENT, LLOYD E., Division of Entomology, Citrus Experiment Station, Riverside, California.
WILLIAMS, ELIOT C., JR., Department of Zoology, Wabash College, Crawfordsville, Indiana.

BOOK NOTICES

INSECTS OF HAWAII, by ELWOOD C. ZIMMERMAN. Vol. 1, xx+206 pp., 52 fig.; vol. 2, viii+475 pp., 228 fig.; vol. 3, vii+255 pp., 110 fig.; vol. 4, vii+268 pp., 92 fig.; vol. 5, vii+464 pp., 238 fig. University of Hawaii Press. 1948.

It is expected that the complete work will involve 12 to 15 volumes; but since there will evidently be a rather long period of time between the publication of volumes 1 to 5 and the appearance of the succeeding volumes it seems appropriate to attempt an appraisal of the parts that have been issued.

In these years of increasingly narrow specialization in insect taxonomy it is almost incredible that one man should attempt to encompass even so large a field as is represented by these first five volumes and still hope to offer a reasonably critical treatment of each group. Zimmerman has done this, however, and he has been amazingly successful. He has not been inhibited by various practices that have become more or less standard with specialists in individual groups, and for that reason he has brought to the subject fresh approaches and original views. To be sure certain portions are somewhat less thoroughly done than others and, of course, mistakes have been made; but no part of the series published thus far can be considered a superficial treatment.

A sharp observer, a skilled taxonomist, and a worker who drives himself relentlessly, Zimmerman has made the most of his many years in the Islands and has acquired a broad understanding of insular faunas in general. This has been of immense help to him in the preparation of the present work. Moreover, he has availed himself freely of the advice and guidance of others with long experience in Hawaii, particularly C. Montague Cook, Otto H. Swezey, C. E. Pemberton, F. X. Williams, and R. H. Van Zwaluwenburg; and he has also called upon specialists in various groups for help with specific problems.

In Volume 1, which is introductory, the author has capably reviewed the geological history of Hawaii, has presented analyses of the biota, including a tabular summary of the endemic Hawaiian insects and a discussion of the flora with a summary of the Hawaiian plants, and has given an interesting account of the development of the endemic fauna.

The remaining four volumes are technical, taxonomic treatments of certain insect groups. Volume 2 covers the Apterygota, represented in Hawaii by only a few forms: Embioptera, of which Hawaii has only one species; Orthoptera; Isoptera; Dermaptera; Zoraptera (a single species); Corrodentia; Mallophaga; Anoplura; Odonata, and Thysanoptera. Many of the illustrations are taken from other publications but there are numerous good original photographs and drawings. Keys to the genera are given, and also keys to the species of most of the larger genera; some of these, particularly for certain large endemic genera of Orthoptera, (e.g., *Paratrigonidium*) are rather weak and will be difficult to use successfully; but on the whole the keys, supported by illustrations and by notes on habitat, hosts, and behavior, will permit recognition of individual forms.

Volume 3 is devoted to the Heteroptera. The nomenclature has been brought up to date; and many species heretofore known only from inadequate descriptions are illustrated, some of them from the holotypes in the British Museum. These illustrations will be of much value in future studies of such families as the Nabidae and Miridae, the Hawaiian species of which are numerous and still largely undescribed.

Volume 4, on Homoptera: Auchenorhyncha, makes it possible for workers to identify the Hawaiian leafhopper fauna with reasonable accuracy, and it provides an excellent starting point for critical taxonomic studies in these groups. Essentially the treatment is synoptic, but some parts are also revisional in that certain erroneous generic placements have been corrected. On the whole the subfamily definitions and allocations of the genera in these subfamilies follow the generally accepted arrangements. It is noted, however, that Typhlocybinae is used for the group properly called Cicadellinae, a course which would leave the family Cicadellidae without a typical subfamily.

Volume 5 deals with the sternorhynchous Homoptera, including the psyllids, aphids, and coccids. The first three of these groups are briefly treated since the Hawaiian representation is very small. There are, however, particularly in the section on aphids, some original illustrations, drawn by Frieda Abernathy, that are excellent. The scale insects and mealybugs of Hawaii have received a good deal of serious attention in the past; furthermore, in developing the section on the Coccoidea, Zimmerman obtained excellent cooperation from the outstanding American specialists in this group. He was thus enabled to give a more thorough treatment than was done for most of the other groups covered in these five volumes. With its numerous, often double-page, anatomical figures (prepared by Professor Ferris after the pattern followed in his Atlas) and the detailed discussions of both the taxonomic and ecological relationships of the species, this section appears to approach the ideal for a restricted faunistic study and it will have utility far beyond the limits of the Hawaiian Islands.

Altogether, approximately 5,000 species of insects have been recorded from the Hawaiian Islands. About 1,100 of these are treated in Volumes 1 to 5 of "Insects of Hawaii." Because our knowledge of them is still very fragmentary, some of the groups can only be covered rather sketchily; but for all groups treated this work should be of immediate value because it brings together references to all the described Hawaiian species for which, in the past, it has been necessary to consult numerous publications, some of them not readily available in most libraries. The author has covered this literature thoroughly and has given a list of the literature consulted at the end of each ordinal treatment. The whole work has been planned and executed with care; it is well printed on paper of good quality, and it is commendable in a high degree. It is a work that will be immensely and increasingly useful to serious students everywhere who attempt to understand the intricacies of insect classification and distribution.—C. F. W. MUESEBECK.

HOW TO KNOW THE IMMATURE INSECTS, by H. F. CHU, vi + 234 pages, 631 figures. Wm. C. Brown Company, Dubuque, Iowa. 1949. Price, $2.00, spiral binding; $3.00, cloth.

The appearance of a second taxonomic manual of immature insects within a few months' time is noteworthy. Dr. Chu's work follows the pictorial key style of the other nature manuals edited by H. E. Jaques, and students who have found this plan useful should have equal appreciation of the present book. It is extremely convenient to have each important step in the key illustrated and to have new technical terms explained by illustrations at the point where they are mentioned, without requiring the user to consult figure or plate on another page. However, this involves repetition of figures and requires publication of a greater number of them. Some of the illustrations are hardly acceptable, although most of them well serve the purpose for which they were intended.

The first part of the book (pages 1–28) briefly discusses metamorphosis, the value of the study of immature insects, the various stages and types, and the technique of collecting, preserving, and rearing. The body of the work (pages 28–216) is devoted to the keys, with some of the more important references (pages 217–223) and an index and pictured glossary (pages 224–234).

In general, one does not find much that is new in the parts devoted to the Holometabola. These keys are mainly adaptations from well-known works such as those of Malloch, Yuasa, Mosher, Bōving and Craighead, and Van Emden. It is, nevertheless, a great advantage to have this material brought together under one cover, along with keys to other groups on which there is no standard treatment. A few errors have been made either typographically or in transcribing the keys; for instance, on page 86, couplet 31b should lead to "40" instead of "42", and on page 91 couplet 42b should lead to "66" instead of "67." The number of such errors, however, appears to be small.

This work will not replace that of Peterson, the first part of which was reviewed in the March, 1949, ANNALS. On the other hand, it should find its own place alongside that more ambitious work, as has been the case with the other manuals of this series.—M. T. J.

REVISTA DEL INSTITUTO DE SALUBRIDAD Y ENFERMEDADES TROPICALES. Secretaria de Salubridad y Enfermedades Tropicales. México, D. F., México.

This journal should not be overlooked by students of medical entomology. It is published quarterly, about 400 pages constituting an annual volume, and is devoted to articles by workers in the Institute, or by others if the articles deal with problems related to those studied at the Institute. Of the articles in volume 9, 1948, seventeen, with a total of 148 pages, deal with medical entomology and related subjects. These are concerned with malaria (3 articles, 24 pages), *Anopheles* taxonomy and rearing (3 articles, 19 pages), mosquito taxonomy other than *Anopheles* (1 article, 4 pages), taxonomy of the Simuliidae (3 articles, 64 pages), onchocerciasis and simuliid control (3 articles, 14 pages), taxonomy of the Trombiculidae (1 article, 10 pages), murine typhus (1 article, 3 pages), phototropism in mosquito larvae poisoned by DDT (1 article, 3 pages), and larvicidal action of DDD (1 article, 7 pages).—M. T. J.

A CENTURY OF ENTOMOLOGY IN THE PACIFIC NORTHWEST, by MELVILLE H. HATCH. v + 43 pages, 9 plates. University of Washington Press, Seattle. 1949. Price, $1.50.

This little book is not of the magnitude of the contributions to the study of the history of entomology by Howard, Weiss, Essig, and Osborn; yet it merits serious consideration along with those important works. It is in a way a kaleidoscopic sketch of those individuals who have entered into the making of Northwestern Entomology, from the ornithologist Dr. John Kirk Townsend, who first collected insects in the area, to the present day.

Dr. Hatch divides the history into four periods, each treated in one chapter: the period of itinerant collectors, the period of resident collectors, the period of established laboratories (1890 to 1930), and the present day (since 1930). A short chapter is devoted to private and institutional collections. The twelve pages of citations include a number of references to arthropod faunistics of the Pacific Northwest, and the usefulness of this list is increased by a taxonomic index following it. The plates are devoted to portraits and photographs of J. M. Aldrich, A. L. Melander, G. W. Taylor, R. C. Treherne, A. L. Lovett, E. H. Blackmore, Ralph Hopping, Orson Bennett Johnson, and Trevor Kincaid.

The material in this work is highly condensed and meaty; in fact, it is regrettable that so much has to be omitted. There is too little space for a discussion of the contributions of the makers of Northwestern Entomology, particularly in the applied fields. The omission of some important names (for example, A. S. Spuler) will be noticed.

By what is obviously a typographical error, the collection of the State College of Washington is said to contain only 45,000 specimens, about one fifth its present size. The 1943 estimate, upon which this figure was probably based, was 145,000.

—M.T.J.

KÄFER UND PILZE, by OTTO SCHEERPELTZ and KARL HOFLER. 351 pages, 19 text figures, 9 plates (8 colored). Verlag fur Jugend und Volk, Wien. Price $5.40.

The appearance of a well-conceived and well-executed book on a specialized field of biology is always news. When the book combines two widely separated fields, is the result of new and extensive researches, and is produced under high standards of publication, the reviewer may use up all his superlatives. And yet, for all this, such a book is likely to interest relatively few biologists, because of its specialization. If it is so written as to give up readily the implications of its conclusions for other fields, it may appeal more widely.

For such a book to be published in the Austria of 1948, with the myriad difficulties surrounding any such venture in post-war times, seems to be a miracle, especially to us in America, where, in spite of relative prosperity, such a thing would not be thought possible.

The present book is a study of the fungi of the forests around Vienna and the beetles that live in association with them. It is an attempt to assemble accurate data concerning the interrelations of these two biological fields.

Drs. Scheerpeltz and Höfler commenced work on this project in 1946, when 35 excursions were made in the vicinity of Vienna to collect fungi and their beetle associates. The careful identification of each fungus, as well as of its associated beetles, is one of the prime contributions of the work. The results of each excursion are given in detail, with a list of the beetle specimens found with each species of fungus.

This is followed by a systematic treatment of the beetles, listing the host fungus for each, with notes on occurrence and distribution. Twenty-two families of beetles (consisting of 176 species represented by 4,041 specimens) are cited from over 118 species of fungus. Of these 176 species, 109 are Staphylinidae.

Ecological analyses are made in several ways, including discussion of biotopes, the pH, smell, and taste of the fungi (chemically), the sociology of the inhabitants, and the succession of visitors. In this section particularly, frequent reference is made to the work of others.

A bibliography of nearly 150 titles provides a major source of information on the entire subject of insect-habitants of fungi, including systematic, geographic, ecologic, morphologic, and physiologic papers.

As if the assembly and publication of this detailed and analytical report was not sufficient for their energies, the authors have illustrated the book with two maps, one graph, 19 text figures containing 55 drawings, one plate of 10 figures showing beetle habitus as well as distinguishing characters, *and* 8 colored plates. The latter show 48 species of beetles and 24 species of fungus.

The systematic section reflects the lifelong interest of Dr. Scheerpeltz in staphylinid beetles. Keys for determination of the Central European species of six genera are given. In addition eight new species and one new subgenus are described (seven species in Atheta, one in Oxypoda; the subgenus Leptharthrophaena in Gyrophaena).

The book is remarkably free from typographical errors and other mechanical defects. Only one is noted, that of the new subgenus *Leptharthrophaena* (pages 164 and 166) as *Lapthartrophaena* (page 170).

This is one of the most satisfying books of its kind ever to come to our attention.—R. E. Blackwelder.

NOTICE TO MEMBERS AND CONTRIBUTORS

The Annals of the Entomological Society of America, published by the Society quarterly, includes the Proceedings of the Annual Meetings and such papers as may be selected by the Editorial Board.

Papers may be submitted to any member of the Editorial Board and should be as nearly as possible in the form desired as final, typewritten, and illustrations finished complete ready for reproduction. Plates must not exceed 4¼x6¾ inches unless intended to fold. Cuts for illustrations are charged at cost to the author. In general, papers to be accepted must be original, complete and previously unpublished. Authors will be allowed fifty reprints gratis and additional copies at cost to the Society.

The Managing Editor is provided with the most recent address of all paid-up members on record in the Secretary's office for mailing the numbers of the Annals and members failing to receive their numbers should present their complaint to the Managing Editor within four months from the date of the mailing of the issue. After that time the numbers will be furnished only at the regular published rate.

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CONTENTS OF THIS NUMBER

PAGE

FISH, WILLIAM A.—Embryology of *Phaenicia sericata* (Meigen) Part III, The Gastrular Tube 121

SLIFER, ELEANOR H.—Variations, During Development, in the Resistance of the Grasshopper Egg to a Toxic Substance 134

MACCREARY, DONALD, AND PAUL L. RICE—Parasites of the European Corn Borer in Delaware 141

NOLAND, JERRE L., J. H. LILLY, AND C. A. BAUMANN—Vitamin Requirements of the Cockroach *Blatella germanica* (L.) 154

MUNSON, SAM C., AND J. FRANKLIN YEAGER—Blood Volume and Chloride Normality in Roaches (*Periplaneta americana* (L.)) Injected with Sodium Chloride Solutions 165

RODECK, HUGO G.—North American Bees of the Genus Nomada, Subgenus Callinomada (Hymenoptera: Apoidea) 174

BECKER, EDWARD C.—A New Species of Ctenicera from the Mid-West (Coleoptera, Elateridae) 187

VOGT, GEORGE B.—A Biologically Annotated List of the Buprestidae of the Lower Rio Grande Valley, Texas 191

WOOLLEY, TYLER A.—Studies on the Internal Anatomy of the Box Elder Bug, *Leptocoris trivittatus* (Say) 203

Proceedings of the Forty-third Annual Meeting of the Entomological Society of America 227

Book Notices 133, 173, 186, 190, 202, 226, 241–244

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